Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN

JOURNAL OF SCIENCE.

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THIRD SERIES.

VOL. XXXIII.—[WHOLE NUMBER, CXXXIII.]

No. 193—JANUARY, 1887.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1887.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. I.—*The Muir Glacier;* by G. FREDERICK WRIGHT.

1. *Description of Glacier Bay.*

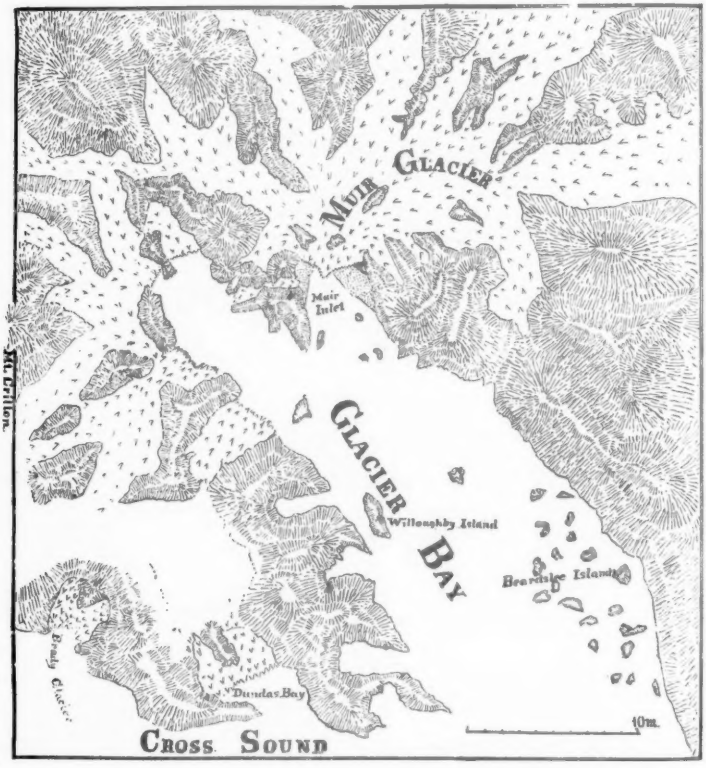
THE Muir glacier enters an inlet of the same name at the head of Glacier Bay, Alaska, in latitude 58° 50′, longitude 136° 40′ west of Greenwich. (See fig. 1.)* Glacier Bay is a body of water about thirty miles long and from eight to twelve miles wide (but narrowing to about three miles at its upper end) projecting in a northwest direction from the eastern end of Cross Sound. The peninsula inclosed between Glacier Bay, Cross Sound and the Pacific Ocean is from thirty to forty miles wide and contains numerous lofty mountain peaks. Mount Crillon, opposite the head of the bay, is 15,900 feet high, and Mount Fairweather, a little farther north, is 15,500 feet. Mounts Lituya and LaPerouse, lying on either side of Crillon, are not far from 10,000 feet above the sea. To the east, between Glacier Bay and Lynn Channel, is a peninsula extending considerably south of the mouth of the bay, and occupied by the White mountains, whose height I am unable to ascertain, but probably having no peaks exceeding 10,000 feet.

Near the mouth of Glacier Bay is a cluster of low islands named after Commander Beardslee, of the U. S. Navy. There are twenty-five or thirty of these, and they are composed of

* The maps have been largely made from original data. They are square with the compass, which bears here, however, 28° east of north.

loose material,—evidently glacial debris,—and are in striking contrast to most of the islands and shores in southeastern Alaska. These, also, like all the other land to the south, are covered with evergreen forests, though the trees are of moderate size. The islands and shores in the upper part of the bay are entirely devoid of forests. Willoughby Island, near the middle of the

1.

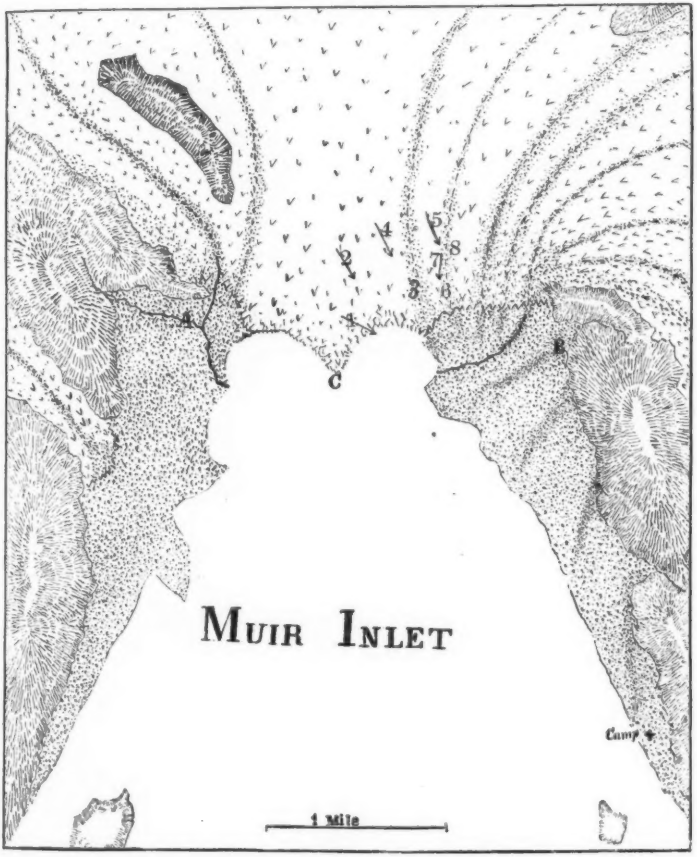


bay, is a bare rock, about two miles long and 1,500 feet high, showing glacial furrows and polishing, from the bottom to the top. Several other smaller islands of similar character in this part of the bay show like signs of having been recently covered with glacial ice.

The upper end of the bay is divided into two inlets of unequal lengths, the western one being about four miles wide and extending seven or eight miles (estimated) in the direction of

the main axis of the bay to the northwest. The eastern, or Muir, inlet is a little over three miles wide at its mouth, and extends to the north about the same distance, narrowing, at the upper end, to a little over one mile, where it is interrupted by the front of the Muir glacier. The real opening between the

2.



mountains, however, is here a little over two miles wide, the upper part on the eastern side being occupied with glacial debris covering a triangular space between the water and the mountain about one mile wide at the ice-front and coming to a point three miles below, beyond which a perpendicular wall of rock 1,000 feet high rises directly from the water. The moun-

tain on the west side of Muir inlet, between it and the other fork of the bay, is 2,900 feet high. That on the east is 3,150 feet high, rising to about 5,000 feet two or three miles back. The base of these mountains consists of metamorphic slate whose strata are very much contorted,—so much so that I found it impossible, in the time at command, to ascertain their system of folds. Upon the summits of the mountains on both sides are remnants of blue crystalline limestone preserved in synclinal axes. In the terminal moraine deposited in front of the glacier on its eastern side are numerous bowlders of very pure white marble coming in medial moraines originating in mountain valleys several miles to the east. Granitic bowlders are also abundant.

2. *Dimensions and characteristics of the Muir Glacier.*

The width of the ice where the glacier breaks through between the mountains is 10,664 feet—a little over two miles. But, as before remarked, the water-front is only about one mile. This front does not form a straight line, but terminates in an angle projecting about a quarter of a mile below the northeast and northwest corners of the inlet. The depth of the water 300 yards south of the ice-front is (according to the measurement of Capt. Hunter of the steamer *Idaho*) 516 feet near the middle of the channel; but it shoals rapidly toward the eastern shore. According to my measurements, taken by leveling up on the shore, the height of the ice at the extremity of the projecting angle in the middle of the inlet was 250 feet; and the front was perpendicular. Back a few hundred feet from the projecting point, and along the front nearer the shores, the perpendicular face of the ice was a little over 300 feet. A little farther back, on a line even with the shoulders of the mountains between which the glacier emerges to meet the water, the general height is 408 feet. From here the surface of the glacier rises toward the east and northeast about 100 feet to the mile. On going out in that direction on the ice seven miles (as near as I could estimate) I found myself, by the barometer, 1,050 feet above the bay.

The main body of the glacier occupies a vast amphitheatre with diameters ranging from thirty to forty miles. This estimate was made from various views obtained from the mountain summits near its mouth when points whose distances were known in other directions were in view. Nine main streams of ice unite to form the grand trunk of the glacier. These branches come from every direction north of the east-and-west line across the mouth of the glacier; and no less than seventeen sub-branches can be seen coming in to join the main streams

from the mountains near the rim of the amphitheatre, making twenty-six in all. Numerous rocky eminences also rise above the surface of the ice, like islands from the sea. The two of these visited, situated about four miles back from the front, showed that they had been recently covered with ice,—their surfaces being smoothed and scored, and glacial debris being deposited everywhere upon them. Upon the side from which the ice approached these islands (the stoss side) it rose, like breakers on the seashore, several hundred feet higher than it was immediately on the lee side. A short distance farther down on the lee side, however, the ice closes up to its normal height at that point. In both instances, also, the lee side of these islands seemed to be the beginning of important subglacial streams of water;—brooks running into them as into a funnel, and causing a backward movement of ice and moraine material, as where there is an eddy in the water. In both these cases the lee sides of these islands were those having greatest exposure to the sunshine. The surface of the ice on this side was depressed from one to two hundred feet below the general surface on the lee side.

The ice in the eastern half of the amphitheatre is moving much more slowly than that in the western half. Of this there are several indirect indications. First, the eastern surface is much smoother than the western. There is no difficulty in traversing the glacier for many miles to the east and northeast. Here and there the surface is interrupted by superficial streams of water occupying narrow, shallow channels, running for a short distance and then plunging down into "*moulins*" to swell the larger current, which may be heard rushing along in its impetuous course far down beneath and out of sight. The ordinary light-colored bands in the ice parallel with its line of motion are everywhere conspicuous, and can be followed on the surface for long distances. When interrupted by crevasses they are seen to penetrate the ice for a depth of many feet, and sometimes to continue on the other side of a crevasse in a different line, as if having suffered a lateral fault. The color of the ice below the surface is an intense blue, and over the eastern portion this color characterizes the most of the surface. Numerous holes in the ice, penetrating downward from an inch or two to several feet and filled with water, are encountered all over the eastern portion. Sometimes there is a stone or a little dirt in the bottom of these, but frequently there is nothing whatever in them but the purest of water. In the shallower enclosures on the surface containing water and a little dirt, worms about as large around as a small knitting needle and an inch long are abundant.

3. *The Moraines.*

The character and course of the moraines on the eastern half of the glacier also attest its slower motion. There are seven medial moraines east of the north-and-south line, four of which come in to the main stream from the mountains to the southeast. (See fig. 2.) Near the rim of the glacial amphitheatre these are long distances, in some cases miles, apart; but, as they approach the mouth of the amphitheatre, they are crowded closer and closer together near its eastern edge, until in the throat itself they are indistinguishably mingled. The three more southern moraines unite some distance above the mouth. One of these contains a large amount of pure marble. This moraine approaches the others on either side until the distance between them disappears, and its marble unites in one common medial moraine a mile or more above the mouth. The fifth moraine from the south is about 150 yards in width, five miles back from the mouth. It is then certainly as much as five, and probably eight, miles from the mountains from which the debris forming it was derived. All these moraines contain many large blocks of stone, some of which stand above the general mass on pedestals of ice, with a tendency always to fall over in the direction of the sun. One such block was twenty feet square and about the same height, standing on a pedestal of ice, three or four feet high. It is the combination of these moraines, after they have been crowded together near the mouth, which forms the deposit now going on at the northeast angle of the inlet just in front of the ice. Of this I will speak more fully in connection with the question of the recedence of the glacier. Similar phenomena, though on a smaller scale, appear near the southwest angle of the amphitheatre.

4. *Indirect evidences of Motion.*

The dominant streams of ice in the Muir glacier come from the north and the northwest. These unite in the lower portion to form a main current, about one mile in width, which is moving toward the head of the inlet with great relative rapidity. Were not the water in the inlet deep enough to float the surplus ice away, there is no knowing how much farther down the valley the glacier would extend. The streams of ice from the east and southwest have already spent the most of their force on reaching the head of the inlet; and, were it not for this central ice-stream, a natural equilibrium of forces would be established here independent of the water, and no icebergs would be formed. The surface of this central current of motion is extremely rough, so that it is entirely out of the question to walk far out upon it. On approaching this portion of

the glacier from the east the transverse crevasses diagonal to the line of motion increase in number and size until the whole surface is broken up into vast parallelograms, prisms and towers of ice, separated by yawning and impassable chasms scores and hundreds of feet in depth. Over this part of the ice the moraines are interrupted and drawn out into thinner lines, often appearing merely as patches of debris on separate masses of ice. This portion of the ice-current presents a lighter colored appearance than other portions, and the roughened lines of motion can be followed, as far as the eye can reach, through distant openings in the mountains to the north and the northwest.

The comparative rapidity of the motion in this part of the ice is also manifest where it breaks off into the water at the head of the inlet. As already said, the perpendicular front of ice at the water's edge is from 250 to 300 feet in height. From this front there is a constant succession of falls of ice into the water, accompanied by loud reports. Scarcely ten minutes either day or night passed during the whole month without our being startled by such reports, and frequently they were like thunder-claps or the booming of cannon at the bombardment of a besieged city, and this though our camp was two and a half miles below the ice-front. Sometimes this sound accompanied the actual fall of masses of ice from the front, while at other times it was merely from the formation of new crevasses or the enlargement of old ones. Repeatedly I have seen vast columns of ice, extending up to the full height of the front, topple over and fall into the water. How far these columns extended below the water could not be told accurately, but I have seen bergs floating away which were certainly 500 feet in length. At other times masses would fall from near the summit breaking off part way down, and splashing the spray up to the very top of the ice, at least 250 feet. The total amount of ice thus falling off could not be directly estimated, but it is enormous. Bergs several hundred feet long and nearly as broad, with a height of from twenty to sixty feet, were numerous and constantly floating out from the inlet. The steamer met such one hundred miles away from the glacier. The smaller pieces of ice often so covered the water of the inlet miles below the glacier that it was with great difficulty that a canoe could be pushed through. One of the bergs measured was sixty feet above water and about four hundred feet square. The portion above water was somewhat irregular, so that probably a symmetrical form thirty feet in height would have contained it. But even at this rate of calculation, the total depth would be two hundred and forty feet. The cubical contents of the berg would then be almost 40,000,000 feet. Occasionally,

when the tide and wind were favorable, the inlet would for a few hours be comparatively free from floating ice; at other times it would seem to be full.

5. *Subglacial Streams.*

The movements of the glacier in its lower portions are probably facilitated by the subglacial streams issuing from the front. There are four of these of considerable size. Two emerge in the inlet itself, and come boiling up, one at each corner of the ice-front, making a perceptible current in the bay. There are also two emerging from under the ice where it passes the shoulders of the mountains forming the throat of the glacier. These boil up, like fountains, two or three feet, and make their way through the sand and gravel of the terminal moraine for about a mile, and enter the inlet 250 or 300 yards south of the ice-front. These streams are perhaps three feet deep and from twenty to forty feet wide, and the current is very strong, since they fall from 150 to 250 feet in their course of a mile. It is the action of the subglacial streams near the corners of the inlet which accounts for the more rapid recession of the glacier front there than at the middle point projecting into the water south of the line joining the east-and-west corners. It was also noticeable that the falls of ice were much more frequent near these corners, and the main motion of the ice as afterwards measured was, not toward the middle point projecting into the inlet, but toward these corners where the subglacial streams emerged below the water.

6. *Direct measurement of the Velocity.*

No small difficulty was encountered in securing direct measurements of the motion; and, as the results may be questioned, I will give the data somewhat fully. As it was impossible to cross the main current of the glacier, we were compelled to take our measurement by triangulation. But even then it seemed at first necessary to plant flags as far out on the ice as it was safe to venture. This was done on the second day of our stay, and a base-line was established on the eastern shore, about a mile above the mouth, and the necessary angles were taken. But on returning to repeat the observations three or four days afterwards it was found that the ice was melting from the surface so fast that the stakes had fallen, and there were no means at command to make them secure. Besides they were not far enough out to be of much service. It appeared also that the base-line was on a lateral moraine, which was, very likely, itself in motion. But by this time it had be-

come evident that the masses of ice uniting to compose the main stream of motion retained their features so perfectly from day to day that there was no difficulty in recognizing many of them much farther out than it was possible to venture to plant stakes. Accordingly another base-line was established on the east side opposite the projecting angle of ice in the inlet. From this position eight recognizable points in different portions of the ice-field were triangulated,—the angles being taken with a sextant. Some of the points were triangulated on five different times, at intervals from the eleventh of August to the second of September. Others were chosen later and triangulated a fewer number of times. In all cases given the angles were taken independently by Mr. Prentiss Baldwin of Cleveland and myself and found to agree.

The base-line finally chosen (marked B on fig. 2) was at the foot of the mountain exactly east by the compass from the projecting angle of ice in the inlet. The elevation of the base-line was 408 feet above tide,—corresponding to that of the ice-front. The distance of this projecting point of ice (marked C on fig. 2) from the base-line was 8,534 feet, and it remained very nearly stationary during the whole time,—showing that the material breaking off from the ice-front was equal to that pushed along by the forward movement. Satisfactory observations were made upon eight other points numbered and located on fig. 2.

No. 1 was a pinnacle of ice 1,476 feet N. by 30° E. from C. The movement from Aug. 14 to Aug. 24 was 1,653 feet E. by 15° S. After this date the pinnacle was no longer visible, having disappeared along the wasting line of front between C and the subglacial stream at the northeast corner of the inlet.

No. 2 was a conspicuous pinnacle of ice 2,416 feet N. by 16° E. of C. Observations were continued upon this from Aug. 11 to Sept. 2. The total distance moved during that time was 1,417 feet, or about sixty-five feet per day. From Aug. 14 to Aug. 24 the movement was 715 feet, or about seventy-one feet per day. The difference is, however, perhaps due to the neglect to record the hours of the day when the observations were taken. As these observations were wholly independent of each other, their substantial concordance demonstrates that there was no serious error in the observations themselves. The direction of movement of this point of ice was very nearly the same as that of the preceding, namely, E. 16° S. This also is towards the subglacial stream emerging from the northeast corner of the inlet.

No. 3 was observed only from Aug. 20 to Aug. 24. It was situated 3,893 feet N. by 62° E. of C, and moved 105 feet in a westerly direction. The westerly course of this movement

probably arose from its being near where the easterly and northeasterly currents joined the main movement.

No. 4 was 5,115 feet N. 42° E. of C, and moved from Aug. 20 to Aug. 24, 143 feet in a southeasterly direction.

No. 5 was 5,580 feet N. 48° E. of C, and moved 289 feet from Aug. 20 to 24 in a direction E. by 39° S.

No. 6 was 5,473 feet N. 70° E. of C, and moved 232 feet from Aug. 11 to Sept. 2 in a direction S. 66° E.

No. 7 was 6,903 feet N. 59° E. of C, and moved 89 feet between Aug. 14 and Aug. 24 in a direction S. 3° E., about nine feet per day.

No. 8 was 7,507 feet N. 62° E. of C, and moved 265 feet from Aug. 14 to Aug. 24 in direction S. 56° E. These last three points lay in one of the moraines on the east side of the line of greatest motion and parallel with it. These moraines are much interrupted in their course by gaps.

Not having a logarithmic table with me in camp these points brought under observation proved much nearer the eastern side than I supposed at the time. But the distances are so great that nothing better could be done from the base-line chosen. I should also have established another base-line on the western side, but stormy weather, and the difficulty of crossing at the times set for doing so, interfered. As the problems are worked out it is observable that the points chosen were all east of the center of the main line of most rapid motion, and are tending with varying velocity toward the northeast corner of the inlet, where the powerful subglacial stream emerges from below the water level. Doubtless on the other side of the center of motion, and at the same relative distance from the front, the ice would be found tending toward the southwest corner, where a similar subglacial stream emerges. I could but wish that some of the points observed had been farther back from the front, but must take the facts as they are. I supposed some of them were farther away, but as they were projected on the distant background the true position could not be told until the actual working out of the problems.

From these observations it would seem to follow that a stream of ice presenting a cross section of about 3,500,000 square feet (5,000 feet wide by about 700 feet deep) is entering the inlet at an average rate of forty feet per day (seventy feet in the center and ten feet near the margin of movement), making about 140,000,000 of cubic feet per day during the month of August. The preceding remarks upon the many indirect evidences of rapid motion render the calculation perfectly credible. What the rate may be at other times of the year there are at present no means of knowing.

7. *The Retreat of the Glacier.*

The indications that the Muir glacier is receding, and that its volume is diminishing, are indubitable and numerous. Little regard need to be paid to the record of Vancouver a hundred years ago, for he did not attempt to enter the bay at all, finding it so full of ice near its mouth as to deter him from it; hence his testimony that the opening was full of ice is so indefinite that it has little bearing upon the condition of the upper portions of the bay at that period of time. Nor need any reliance be placed on the traditions of the Indians to the effect that within the memory of their grandfathers the ice extended several miles farther down than at the present time. The Indians now rarely visit the head of the inlet, and the quantity of ice floating on the surface varies so much from day to day, and presumably from month to month, that great diversity of impressions might be received at times separated by even short intervals. The convincing evidence of the recent retreat of the glaciers of this bay from ground formerly occupied by them is of physical character.

The islands of Southern Alaska are ordinarily covered with forests of cedar, hemlock and fir up to the level of perpetual snow. To this rule the shores and islands of the upper part of Glacier Bay are a striking exception. Near the mouth of the bay forests continue to occur as in other parts, only on a diminished scale; but in the upper half of the bay all shores and islands are perfectly bare of forests, and the rocks retain in the most exposed situations fresh grooves and striæ of glacial origin. It would be impossible for rocks so exposed in such a climate, to retain these for an indefinite length of time. Far up on the mountains, also, there are remnants of glacial debris in situations such that the material could not have resisted erosive agencies for any great length of time. The triangular shaped terminal moraine on the eastern side, just below the ice-front, presents some interesting features bearing on the same point. This extends three miles below the glacier, and in its lower portions is thinly covered with vegetation. This covering becomes less and less abundant as the glacier is approached, until, over the last mile, scarcely any plants at all can be found. Apparently this is because there has not been time for vegetation to spread over the upper portion of the moraine since the ice withdrew, for on the mountains close by, where the exposure has been longer, there is a complete matting of grass, flowering plants, and shrubs. Again, in this triangular moraine-covered space, there are five distinct transverse ridges marking as many stages in the recession of the ice-front. (See fig. 2.) These moraines of retrocession run

parallel with the ice-front on that side, and at about equal distances from each other, each one rising from the water's edge to the foot of the mountain, where they are 408 feet above tide. An inspection of the upper moraine ridge shows the manner of its formation. This transverse ridge is one-half mile below the ice-front, and is still underlaid in some portions with masses of ice thirty feet or more in thickness, which are melting away on their sides and allowing the debris covering them to slide down about their bases. Kettle-holes are in all stages of formation along this ridge. The sub-glacial stream emerging from the southeast corner of the glacier next the mountain rushes along just in the rear of this moraine ridge and in front of a similar deposit in process of formation on the very edge of the ice where the medial moraines spoken of terminate. Eventually this stream will break out in the rear of that deposit, also, and leave another ridge similar to the one now slowly settling down into position south of it. This first ridge south of the sub-glacial stream, with its ice still melting in exposed positions under its covering of gravel, can not be many years old.

Still another sign of the recent date of this whole moraine appears at various places where water courses coming down from the mountain are depositing superficial deltas of debris upon the edge of the older glacial deposit. These deltas are very limited in extent, though the annual deposition is by no means insignificant. At the southern apex of the moraine, three miles below the ice-front, and but one or two hundred yards from our camp, great quantities of debris came tearing down in repeated avalanches during a prolonged season of rain. Twenty-five years would be ample time for the formation of the cone of debris at the foot of this line of avalanches. Thus there can be no reasonable doubt that during the earlier part of this century the ice filled the inlet several miles farther down than now. And there can be scarcely less doubt that the glacier filled the inlet, as recently as that, 1,000 or 1,500 feet above its present level near the front. For the glacial debris and striæ are very marked and fresh on both mountains flanking the upper part of the inlet up to 2,500 feet, and the evidences of an ice movement in the direction of the axis of the bay are not wanting as high as 3,700 feet on the eastern mountain, upon which I found fresh striæ running north by south and directly past the summit, which rises 1,000 or 1,500 feet still higher just to the east.

8. *A Buried Forest.*

All this is necessary to a comprehension of one of the most interesting of problems, presented by the buried forests near the

southwest corner of the glacier. (See A, fig. 2.) Below this corner, and extending for about a mile and a half, there is a gravel deposit, similar to that on the eastern side, except that it is not marked by transverse ridges, but is level-topped, rising gradually from about 100 feet at its southern termination to a little over 300 feet where it extends north and west of the ice-front. (See fig. 2.) The sub-glacial stream entering the inlet just below the southwest corner of the ice emerges from the ice about a mile farther up, on the north side of the projecting shoulder of the western mountain which forms that side of the gateway through which the ice enters the inlet. This stream comes principally from the decaying western branch of the glacier before alluded to, and, after winding around the projecting shoulder of the mountain (this shoulder is 315 feet A. T.), has worn a channel through the gravel deposit lying between the lower mile of the glacier and the mountain a short distance to the southwest. About half-way down, a small brook, coming from between this latter mountain and that whose shoulder forms the western part of the gateway just north of it, joins the main stream issuing from the glacier on this side. Where these streams unite at A they are now uncovering a forest of cedar trees in perfect preservation, standing upright in the soil in which they grew, with the humus still about their roots. An abundance of their cones, still preserving their shape, lies about their roots; and the texture of the wood is still unimpaired. One of these upright trunks measured ten feet in circumference about fifteen feet above the roots. Some of the smaller upright trees have their branches and twigs still intact, preserving the normal conical appearance of a recently dead cedar tree. These trees are in various stages of exposure. Some of them are uncovered to the roots, some are washed wholly out of the soil, while others are still buried and standing upright, in horizontal layers of fine sand and gravel, some with tops projecting from a depth of twenty or thirty feet, others being doubtless entirely covered. The roots of these trees are in a compact, stiff clay stratum, blue in color, without grit, intersected by numerous rootlets as long as a knitting needle, which is, in places, twenty feet thick. There is also, occasionally in this substratum of clay a small fragment of wood, as well as some smooth pebbles from an inch to two feet in diameter. The surface of this substratum is at this point 85 feet above the inlet. The deposit of sand and gravel covering the forest rises 115 feet higher and is level-topped at that height, but rising toward the north till it reaches the shoulder of the mountain at an elevation of 300 feet. The trees are essentially like those now growing on the Alaskan mountains. Many of them have been violently broken off from five to

twenty feet above their roots. This has been done by some force that has battered them from the upper side at the point of fracture. Evidently cakes of ice brought down by the streams indicated in the map, when flowing at various higher levels than now, have accomplished this result. For the trunks in the main stream were battered on the north side, while those in the gully worn by the lateral stream were battered from the west side.

From this description the explanation of this buried forest would seem to be evident enough. At some period, when the ice occupied only the upper part of the valley to the north of this point, forests grew over all the space lying southwest of the present ice-front. As the ice advanced to near its present position, the streams carrying off the surplus water from the western half of the advancing glacier were suddenly turned into the protected space occupied by this forest, where they deposited their loads of sand and gravel. A cause very likely combining to facilitate deposition in this spot has not yet been spoken of, but is evident when on the ground, and from a glance at the map. A transverse valley passes just below this point from Muir inlet to the western inlet into which Glacier Bay divides. This transverse valley is at present occupied by a decaying glacier opening into both inlets, and sending a sub-glacial stream, through a long, narrow series of moraines, into Muir inlet about two miles to the south. Now, when a general advance of the ice was in progress, this transverse stream probably pushed itself down into the inlet across the path of the ice moving from the north, and so formed an obstruction to the water running from the southwest corner of the main glacier, thus favoring the rapid deposition which so evidently took place. When this enclosed place was filled up, and the advancing ice had risen above and surmounted the projecting shoulder of the mountain just to the north, that rocky barrier protected a portion of the forest from the force of the ice movement, causing the ice to move some distance over the top of the superincumbent gravel before exerting its full downward force. Thus sealed up on the lee side of this protecting ridge of rock, there would seem to be no limit to the length of time the forest might be preserved. I see no reason why this forest may not have antedated the Glacial period itself.

The existence of other forests similarly preserved in that vicinity is amply witnessed to by many facts. One upon the island near the west shore, four miles south, is now exposed in a similarly protected position. Furthermore, the moraine, already described on the east side of the inlet, contains much wood ground up into slivers and fragments. Indeed, our whole dependence during the month for fuel was upon such fragments

lying exposed in the moraine. Occasional chunks of peat or compact masses of sphagnum formed a part of the debris of this moraine. These also occurred on some of the medial moraines on the eastern side. I did not go up them far enough to learn directly their origin. But, as no forests were visible anywhere in that direction, it is presumable that they had been recently excavated from preglacial forests similar in situation to that now exposed on the west below the ice-front.

The capacity of the ice to move, without disturbing them, over such gravel deposits as covered the forests, is seen in the present condition of the southwestern corner of the glacier itself. As the ice-front has retreated along that shore, large masses of ice are still to be seen lapping over upon the gravel. These are portions of the glacier still sustained in place by the underlying gravel while the water of the inlet has carried the ice from the perpendicular bank clear away. This phenomenon, and that of the general perpendicular front presented by the ice at the water's edge, accords with the well-known fact that the surface of the ice moves faster than the lower portions. Otherwise the ice columns at the front would not fall over into the water as they do.

9. *Kames and Kettle-holes.*

The formation of kames, and of the knobs and kettle-holes characteristic both of kames and of terminal moraines, is illustrated in various places about the mouth of Muir glacier, but especially near the southwest corner just above the shoulder of the mountain where the last lateral branch comes in from the west. This branch is retreating, and has already begun to separate from the main glacier at its lower side, where the sub glacial stream passing the buried forest emerges. Here a vast amount of water-worn debris covers the ice, extending up the glacier in the line of motion for a long distance. It is evident from the situation that, when the ice-stream was a little fuller than now, and the sub-glacial stream emerged considerably farther down, a great mass of debris was spread out on the ice at an elevation considerably above the bottom. Now that the front is retreating, this sub-glacial stream occupies a long tunnel, twenty-five or thirty feet high, in a stratum of ice that is overlaid to a depth in some places of fifteen or twenty feet with water-worn glacial debris. In numerous places the roof of this tunnel has broken in, and the tunnel itself is deserted for some distance by the stream, so that the debris is caving down into the bed of the tunnel as the edges of ice melt away, thus forming a tortuous ridge, with projecting knolls where the funnels into the tunnel are oldest and largest. At the same time,

the ice on the sides at some distance from the tunnel, where the superficial debris was thinner, has melted down much below the level of that which was protected by the thicker deposit; and so the debris is sliding down the sides as well as into the tunnel through the centre. Thus three ridges approximately parallel are simultaneously forming. When the ice has fully melted away, this debris will present all the complications of interlacing ridges, with numerous kettle-holes and knobs characterizing the kames; and these will be approximately parallel with the line of glacial motion. The same condition of things exists about the head of the sub-glacial stream on the east side, also near the junction of the first branch glacier on the east with the main stream, as also about the mouth of the independent glacier shown on the map lower down on the west side of the inlet. (See fig. 2.) The formation of kettle-holes in the terminal ridges has already been referred to. (See p. 12.)

10. *Transportation and waste by Water.*

Considerable earthy material is carried out from the front by the bergs. Pebbles and dirt were frequently seen frozen into them as they were floating long distances away. Just how many of the bergs were formed from ice that originally rested on the bottom of the inlet I have no means of telling. That some were so formed seems exceedingly probable, if for no other reasons because of the great amount of debris that was sometimes seen frozen into them. It is by no means certain that the subglacial streams boiling up near the upper corners of the inlet were beneath the lowest stratum of ice. Some small streams were seen pouring out from the face of the ice half way up from the water. It seems likely that a great amount of sediment becomes incorporated in cavities in the center of the glacier through the action of these subglacial streams; and so is ready for transportation when the masses break loose.

There were two pretty distinct lines of motion in the currents of the inlet, corresponding to those originating in the subglacial streams, so that ordinarily the ice-floes arranged themselves in the inlet along definite lines. But the tides were so high as sometimes to cause much irregularity. Frequently large icebergs would be seen moving up the lines of current or diagonal to them. The upper part of the inlet was filled with the muddy water coming from the subglacial streams. The line separating this muddy water from the clear water of the bay was driven now one way and now another, according to the influence of the tide. The steamer's screw brought up much muddy water from below the surface some distance down the bay, and

where the surface was clear. The sediment forming over the bottom of the bay must resemble the loess of the Missouri and Mississippi valleys.

11. *Other Glaciers reaching the Bay.*

Besides the Muir glacier there are four others of large size entering the longer inlet to the west, (see fig. 1.) These have their origin on the flanks of Mounts Crillon and Fairweather. They have never been studied, but are apparently as accessible as the Muir. Professor Muir and Rev. Mr. Young are the only well-informed persons who have visited them, and their stay was brief. I went about half way up the inlet, on its east side, and took some photographs from points where the whole outlines could be seen. I also saw them from the mountains on the east side. The general appearance does not differ materially from that of the Muir glacier. To complete the study one needs a small steam launch, and more ample time and preparation than we could command.

The moisture of the climate is a serious drawback to investigations in all that region, though this is very favorable to the growth of glaciers. The annual precipitation over southeastern Alaska averages from eighty to one hundred inches. The average number of days per annum on which rain or snow has fallen at Sitka during the last fifty years is 198, while some years it has been as high as 264. Fifteen of the twenty-nine days we were in Glacier Bay (from Aug. 4 to Sept. 2) were so rainy as to render observation impossible. The other days were however, clear and beautiful beyond description. The absence of forests also renders it easy to climb the mountains and observe from them. It is to be hoped that other expeditions better fitted than ours, and prepared to spend a longer time, will soon make a more complete study of this now easily accessible and most fruitful field for glacial investigation.

12. *Temperature.*

I append the record of the thermometer from Aug. 20 to Aug. 31, giving the mean of three readings each day taken at 8 A. M., 2 P. M., and 8 P. M. The temperature of the water in the upper part of the inlet was uniformly 40° F.

Aug. 20	49·4° F.	Aug. 26	51·9° F.
Aug. 21	48·9° F.	Aug. 27	46·1° F.
Aug. 22	46·1° F.	Aug. 28	50·5° F.
Aug. 23	44·6° F.	Aug. 29	45° F.
Aug. 24	49·8° F.	Aug. 30	54·8° F.
Aug. 25	52·7° F.	Aug. 31	50·5° F.

13. *Flora.*

The following is the list of plants, as identified by Professor Asa Gray, found in bloom about Muir inlet during the month of August. Where the altitude is not given they were found near the tide.

Arabis ambigua, Brong.	Aug.	26	1600 A. T.
Arenaria peploides, L.		28	
Astragalus alpinus, L.		7	
Hedysarum boreale, Nutt.		28	
Sanguisorba Canadensis		6	
Lutkea sibbaldioides, Brong.		27	
Saxifraga Lyalli, Engl.		26	1600 A. T.
stellaris, L.		27	3000 A. T.
Parnassia fimbriata, Small		27	3000 A. T.
palustris, L.		6	
Epilobium latifolium, L.		6	1600 A. T.
origanifolium, Lam. (?)		28	
Solidago multiradiata, Ait.		27	
Erigeron salsuginosus, Gray, arctic form		27	3000 A. T.
Antennaria margaritacea, arctic form		27	
Achillea millefolium, L., arctic var.		27	
Arnica obtusifolia, Les.		27	1200 A. T.
Campanula rotundifolia, L., var. Alaskana		28	
Gentiana platypetala (?)		27	
" Menziesii (?)		27	
Mertensia maritima		7	
Castilleja parviflora, Brong.		28	
Salix vestita, Pursh		6	
Habenaria hyperborea, R. Br.		27	2650 A. T.
Luzula parviflora, Meyer			
Poa alpina, var. vivipara		26	1500 A. T.
Poa alpina, L.		26	1600 A. T.
Poa laxa, Hænke		26	1500 A. T.
Phleum alpinum, L.		26	1600 A. T.
Elymus mollis		6	
Hordeum, sp. (?)		6	

ART. II.—*On the Age of the Coal found in the region traversed by the Rio Grande;* by C. A. WHITE.

DURING the past few years many discoveries of coal have been made within the region which is traversed by the lower portion of the Rio Grande, besides those which were made by the members of the United States and Mexican Boundary Commission and other early government expeditions. In Texas, coal has been found in Webb, Maverick, Presidio and El Paso

counties; and in Mexico, in the States of Nuevo Leon and Coahuila. By certain local geologists and mining experts, whose reports have fallen under my observation, a part of these coals have been referred to Carboniferous age, and others to Triassic* age. From personal examination in the field, extending over a large part of the region in question, and an examination of fossils which have been collected by different persons† from strata associated with the coals, I am satisfied, however, that none of them are of earlier than late Cretaceous age.

In some cases the coal of this region is worthless for practical use, but in others it is of good quality; all of it having the general characteristics of the coals which are obtained from the Laramie and Fox Hills formations in Colorado, Utah and Wyoming. From the data and observations just mentioned I do not hesitate to refer all the known coal of the region under consideration to one or the other, or both, of those formations.

In the region of the Lower Rio Grande these two formations appear to be as intimately associated with each other as they are to the northward. Their strata are so similar in general character that it is usually difficult to define a plane of demarkation between them, and in the absence of paleontological evidence it is often difficult or impracticable to distinguish the one from the other.

I have at present no evidence of the presence of the Laramie formation in Webb and Maverick counties, Texas, the coal which has hitherto been found there belonging to the equivalent of the Fox Hills Group of the Cretaceous period. The mines at Santa Tomas, some forty miles above Laredo, and those seven miles above Eagle Pass, are the principal ones on the Texas side of the river. The equivalent of the latter coal is also found on the Mexican side, a few miles from Piedras Negras, opposite Eagle Pass.

From data furnished by Mr. Gardiner, I also learn that both the Laramie ‡ and Fox Hills formations exist on the Mexican side of the Rio Grande, in the northern part of the State of Nuevo Leon and the adjacent eastern portion of the State of Coahuila, and that both formations are coal-bearing there.

On the occasion of a late journey in Coahuila, I found both these formations to be well developed in the region which is

* In an otherwise important article by W. H. Adams, M.E.; in the Trans. Inst. Mining Engineers, vol. x, pp. 270–273, entitled Coals in Mexico, Santa Rosa District, he refers the coal-bearing rocks there to Triassic age; and those at Eagle Pass to the Permian, both of which references are erroneous.

† The collections referred to were made by Mr. James T. Gardiner, of New York, Mr. W. F. Cummins, of Dallas, Texas, and Mr. R. T. Hill, of the U. S. Geological Survey.

‡ See this Journal, III, vol. xxv, pp. 207 et seq.

traversed by the Rio Sabinas, a tributary of the Rio Grande. I traced the Laramie strata along the north side of the Sabinas valley for a distance of nearly forty miles, beginning a few miles above Sabinas station of the Mexican and International Railroad, and going down the valley to the southeastward. At the hamlet of San Felipe, about fifteen miles below Sabinas station, some important mines have been opened in the Laramie Group on both sides of Rio Sabinas; and the presence of coal in the same formation has been proved at several other localities in the same district.

On the south side of the river, some twenty miles southwestward from Sabinas station, and westward from the railroad, exposures of coal were observed in strata equivalent with the Fox Hills Group, but no important mines have yet been opened there.

Little is yet known of the character of the coal deposits in the southern part of Presidio and El Paso counties, Texas, respectively; but the coal which is found at White Oaks in Southeastern New Mexico, some 75 miles northeastward from El Paso, is reported to be of good quality. Coal of either Laramie or Fox Hills age, or both, is also well known to exist at many localities in New Mexico and Colorado, along the eastern base of the mountains. It will thus be seen that there is a belt of these two coal-bearing formations extending nearly or quite continuously from the valley of the South Platte in Colorado to the State of Nuevo Leon in Mexico.

It is not necessary to inform the practical geologist that this series of strata is entirely distinct from the coal-bearing rocks of Carboniferous age which extend southward through the Indian Territory into Northern Texas, and also distinct from the Tertiary lignite beds which range through eastern Texas and portions of other Gulf States.

Art. III.—*The Viscosity of Steel and its Relations to Temper;* by C. Barus and V. Strouhal.

[Continued from vol. xxxii, page 466.]

Miscellaneous experiments.—1. In tables 27 and 28 we cite the results obtained when one of the steel rods is replaced by a fiber of glass. The mean thickness or the diameter $2\rho_g$ of glass was intended to be that of the steel rod $2\rho_s$; but it is smaller in table 27 and considerably larger in table 28. It is impossible to store a greater total torsion than $\psi_1-(-\psi_2)=90°$ in the given system without breaking the glass fiber. The equality of ψ_1 and ψ_2 is assumed merely for convenience in des-

ignation (cf. p. 30). In table 28, moreover, the glass-hard rod used during the first half of the experiment is replaced by an annealed rod in the second half, leaving the glass fibre unaltered. The suspension here is practically unifilar, since it is nearly impossible mechanically to clutch the glass fiber without breaking it.

TABLE 27.—APPARATUS I.

R=215^{cm}; L=27^{cm}; l<0·2^{cm}. Rods: No. 35, glass-hard steel, ψ_1=+45°: No. *a*, glass fiber, ψ_2=−45°; ρ_s=0·082^{cm}; ρ_g=0·070^{cm}.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
29/6, 3^h 20^m	(*)	0 00	(*)	3/7, 8^h 17^m	0·974	88·95	1·075
3 42	−0·129	0·37	−0·028	12 12	0·991	92·87	1·092
4 20	−0·101	1·00	±0·000	6 27	1·026	99·12	1·127
5 30	−0·052	2·17	+0·049	4/7, 9^h 45^m	1·098	114·42	1·199
5 51	−0·031	2·52	0·070	12 09	1·109	116·82	1·210
30/6, 8^h 50^m	+0·351	17·50	0·452	3 06	1·116	119·77	1·217
12 23	0·413	21·05	0·514	5 59	1·145	122·65	1·246
1 57	0·440	22·62	0·541	5/7, 9^h 39^m	1·213	138·32	1·314
5 22	0·486	26·03	0·587	12 00	1·228	140·67	1·329
1/7, 8^h 37^m	0 652	41·28	0·753	4 43	1·257	145·38	1·358
2 12	0·706	46·87	0·807	6/7, 8^h 40^m	1·318	161·33	1·419
4 36	0·732	49·27	0·833	1 52	1·339	166·53	1·440
5 37	0·741	50·28	0·842	5 15	1·355	169·92	1·456
6 57	0·753	51·62	0·854	7/7, 8^h 49^m	1·420	185·48	1·521
2/7, 9^h 19^m	0·854	65·98	0·955	1 27	1·443	190·12	1·444
1 45	0·879	70·42	0·980				
5 09	0·899	73·82	1·000				

TABLE 28.—APPARATUS I.

R=223^{cm}; L=23^{cm}. Rods: No. 36, glass-hard steel, ψ_1=+45°; No. *b*, glass fiber, ψ_2=−45°. $2\rho_s$=0·082^{cm}; 0·085^{cm}<$2\rho_g$<0·120^{cm}.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
7/7, 4^h 15^m	(*)	0·00	(*)	12/7, 7^h 35^m	3·100	111·33	−0·235
4 26	2·995	0·18	−0·130	Glass-hard rod replaced by soft steel rod, viz: No. 42, annealed, 450°, 1^h, ψ_1=+45°, 2ρ=0·082^{cm}.			
4 38	2·934	0·38	−0·069				
5 15	2·865	1·00	±0·000	12/7, 9^h 39^m	(*)	0·00	(*)
8/7, 9^h 14^m	2·823	16·98	+0·042	9 49	1·358	0·17	−0·023
12 41	2·841	20·43	0·024	10 54	1·331	1·25	+0·004
4 07	2·858	23·87	0·007	5 25	1·303	7·77	0·032
5 47	2·863	25·53	0·002	13/7, 8^h 26^m	1·278	22·78	0·057
9/7, 8^h 33^m	2·912	40·30	−0·047	12 27	1·270	26·80	0·065
12 10	2·928	43·92	−0·063	5 6	1·270	31·45	0·065
5 16	2·940	49·02	−0·075	14/7, 8^h 50^m	1·258	47·18	0·077
10/7, 8^h 04^m	2·983	63·82	−0·118	12 48	1·258	51·15	0·077
12 08	2·996	67·88	−0·131	4 40	1·255	55·02	0·080
5 18	3·010	73·05	−0·145	15/7, 10^h 45^m	1·245	73·10	0·090
11/7, 9^h 07^m	3·053	88·87	−0·188	4 25	1·245	78·77	0·090
11 23	3·058	91·13	−0·193	16/7, 9^h 16^m	1·237	95·62	0·098
5 21	3·077	97·10	−0·212	1 42	1·237	100·05	0·098
6 59	3·081	98·73	−0·216	5 54	1·236	104·25	0·099

* Adjusted.

2. Tables 29, 29A, 30, contain a part of our results in which one steel wire is replaced by a wire of wrought iron, annealed or drawn as specified. That the amounts of torsion are equal in angle (ψ) is again assumed for convenience of designation only. ρ_s is the radius of steel, ρ_i of the iron wire. The applied couple twists soft iron beyond the limits of elasticity and the amount of instantaneous detorsion is here probably as large as $\frac{1}{2}(\psi_1+\psi_2)$. In case of steel instantaneous detorsion is nearly zero.

TABLE 29.—APPARATUS I.

R=223^{cm}; L=26^{cm}; l<0·2^{cm}. Rods: No. 37, steel, annealed, 450°, 1^h, ψ=+180°; No. *c*, wrought iron, drawn, ψ=−180°. $2\rho_s$=0·082^{cm}; $2\rho_i$=0·083^{cm}.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
17/7, 4^h 20^m	1·955	0·20	−0·387	18/7, 8^h 27^m	2·177	16·32	−0·165
4 23	2·032	0 25	−0·310	2· 24	2·122	22·27	−0·220
4 27	2·113	0·32	−0·229	19/7, 9^h 37^m	2·032	41·48	−0·310
4 51	2·285	0·72	−0·057	12 19	2·025	44·18	−0·317
5 20	2·342	1·20	±0·000	5 10	2·014	49·03	−0·328
6 01	2·362	1·88	+0·020	20/7, 8^h 29^m	1·984	64·35	−0·358
				3 45	1·977	71·62	−0·364

* Adjusted $\tau-b-f$.

TABLE 30.—APPARATUS II.

R=200^{cm} L=27^{cm}; l<0·2^{cm}. Rods: No. 38, steel, annealed 450°, 1^h, ψ=+180°; No. *d*, wrought iron, soft, ψ=−180°. $2\rho_s$=0·082^{cm}; $2\rho_i$=0·112^{cm}.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
16/7, 9^h 40^m	(*)	0·00	(*)	18/7, 8^h 33^m†	0·146	15·12	(0·153)
9 48	0·714	0·13	−0 026	2 35	0·151	21·15	(0·148)
11 14	0·745	1·57	+0·005	19/7, 9^h 35^m	0·128	(40·20)	(0·171)
1 48	0·758	4·13	0·018	12 20	0·119	(42·90)	(0·180)
5 47	0·750	8·23	0·010	5 10	0·110	(47·73)	(0·189)
17/7, 8^h 47^m	0·731	23·12	−0·009	20/7, 8^h 28^m	0·082	(63·03)	(0·217)
Thick iron wire replaced by thin wire. Rod No. 9, wrought iron, soft; ψ=−180°; 2ρ=0·083^{cm}.				3 44	0·064	(70·32)	(0·235)
17/7, 5^h 26^m	0·755	*0·00	−0·019				
5 30	0·745	0·07	−0·009				
5 36	0·736	0·17	±0·000				
6 00	0·718	0·57	+0·018				

* Accident, new adjustment, data otherwise good, but distinguished by parentheses.

† Adjusted $\tau-l-f$. ‡ Adjusted $\tau+l+f$, but the time not accurately noted.

TABLE 30A.—APPARATUS II.

R=202^{cm}; L=26^{cm}; l<0·2^{cm}. Rods: No. 50, annealed 350°. 1^h, ψ=+180°; No. *k*, wrought iron drawn, ψ=−180°. $2\rho_i$=0·084^{cm}; $2\rho_s$=0·082^{cm}.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
23/8, 2^h 00^m	(*)	0·00	(*)	27/8, 9^h 10^m	1·483	96·38	0·114
2 13	2·052	0·22	−0·452	7 36	1·490		
2 20	1·914	0·33	−0·314	28/8, 9^h 21^m	1·492	120·13	0·107
3 11	1·599	1·18	+0·001	6 55	1·494		
5 37	1·417	3·62	0·183	29/8, 10^h 11^m	1·500	144·23	0·100
7 11	1·392	5·18	0·208	6 17	1·501		
24/8, 9^h 17^m	1·385	19·28	0·215	30/8, 9^h 11^m	1·505	163·18	0·095
5 13	1·411	27·22	0·189	31/8, 1^h 19^m	1·515	193·66	0·085
25/8, 9^h 05^m	1·435	43·08	0·165	6 00	1·515		
7 00	1·448	53·02	0·152	1/9, 9^h 19^m	1·517	211·32	0·083
26/8, 9^h 10^m	1·460	70·65	0·135	2/9, 9^h 05^m	1·524	237·29	0·074
4 08	1·469						

3. Tables 31 and 32 contain our results with the tubular apparatus. ρ_1 is the inner radius, ρ_2 the outer radius of the tube. Q and q denote the right sections of brass tube and steel wire respectively. Of course sections of metallic surface are meant. The inclosed wire is twisted alternately in opposite directions as is indicated by the sign of ψ. The result is similarly indicated by the sign of φ. Subscripts s and b refer to steel and brass respectively. Table 31 contains results for a thick tube, table 32 for a thin tube. Hard or soft rods are inserted, as indicated.

Table 34 is mentioned below.

TABLE 31.—APPARATUS (tubular) II.

$R=260^{cm}$; $L=22^{cm}$. Rods: No. *e*, brass, $2\rho_1=0{\cdot}188^{cm}$. $2\rho_2=0{\cdot}320^{cm}$. No. 89, steel, glass-hard, $2\rho=0{\cdot}127^{cm}$; $Q=0{\cdot}053^{cm^2}$; $q=0{\cdot}0127^{cm^2}$; $Q/q<4{\cdot}5$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
7/7, 9h 02m	0·308	*0·00	+0·002
12 15	0·390	3·22	−0·080
5 18	0·420	8·27	−0·110
8/7, 9h 19m	0·460	24·28	−0·150
12 48	0·465	27·77	−0·155
5 50	0·476	32·80	−0·166
9/7, 8h 30m	0·500	47·47	−0·190
9/7, 8h 50m	0·456	†0·00	−0·056
12 12	0·337	3,37	+0·063
5 20	0·283	8·50	+0·117
10/7, 8h 09m	0·222	23·32	+0·178
12 09	0·208	27·32	+0·192
5 18	0·191	32·47	+0·209
11/7, 9h 20m	0·160	48·50	+0·240
11 35	0·151	50·75	+0·249
4 15	0·142	55·42	+0·258
11/7, 4h 15m	0·540	*0·00	+0·060
4 45	0·575	0·50	+0·025
5 23	0·597	1·13	+0·003
7 00	0·630	2·75	−0 030
12/7, 7h 39m	0·718	15·40	−0·118
5 29	0·743	25·23	−0·143
13/7, 8h 30m	0·779	40·25	−0·179
Glass-hard rod replaced by a soft steel rod, viz: No. 40, annealed, 450°, 1h, $2\rho=0{\cdot}127^{cm}$.			
13/7, 10h 04m	0·876	*0·00	+0·004
12 30	0·886	2·43	−0·004
5 05	9·890	7·02	−0·010
14/7, 8h 55m	0·894	22·85	−0·014
14/7, 8h 57m	0·248	*0·00	±0·000
10 27	0·248	1·50	±0·000
12 45	0·248	3·80	±0·000
4 45	0·250	7·80	+0·002
15/7, 10h 46m	0·250	25·82	+0·002
15/7, 10h 46m	....	*0·00	....
12 35	0·310	1·82	−0·005
4 27	0·306	5·68	−0·009
16/7, 9h 20m	0·299	22·57	−0·016
Original hard steel rod, No. 39, again inserted.			
16/7, 9h 25m	0·948	*0·00	+0·032
11 26	1·009	2·02	−0·029
1 45	1·028	4·33	−0·048
5 58	1·052	8·55	−0·072
17/7, 8h 50m	1·093	23·42	−0·113
12 55	1·102	27·50	−0·122
6 04	1·125	32·65	−0·145
18/7, 8h 27m	1·151	47·03	−0·171
2 28	1·160	53·05	−0·180
19/7. 9h 41m	1·185	72·27	−0·205
12 20	1·186	74 92	−0·206
5 15	1·186	79 83	−0·206
20/7, 8h 28m	1·207	95·06	−0·227
20/7, 10h 50m	0·458	†0·00	−0·062
11 18	0·416	0·47	−0·020
11 50	0·396	1·00	±0·000
1 53	0·354	3·05	+0·042
3 44	0·330	4·90	+0·066
6. 35	0·303	7·75	+0·093
21/7, 10h 02m	0·247	23·20	+0·149
12 18	0·239	25·47	+0·157

* Total twist $\psi_s-(-\psi_b)=180°$, twist of steel ψ_s positive.
† Total twist $-\psi_s+(-\psi_b)=180°$, twist of steel, positive.

TABLE 32.—APPARATUS (tubular) V.

R=260^{cm}; L=22^{cm}. Rods: No. *f*, brass tube, $\begin{cases} 2\rho_1=0{\cdot}19^{cm}. \\ 2\rho_2=0{\cdot}24^{cm}. \end{cases}$ No. 41, steel, annealed 450°, 1^h, 2ρ=0·082^{cm}. Q=0·0155$^{cm^2}$; q=0·0054$^{cm^2}$; $Q/q>2{\cdot}5$.

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
22/7, 3^h 38^m	----	†0·00	----	28/7, 9^h 32^m	1·476	120·14	0 392
3 48	3·602	0·17	+0·032	1 18	1·498		
5 39	3·541	2·02	−0·029	4 26	1·502		
7 13	3·518	3·58	−0·053	29/7, 9^h 04^m	1·511	143·86	0·417
23/4, 7^h 54^m	3·465	‡16·27	−0·105	12 48	1·518		
12 02	3·435	20·40	−0·135	4 33	1·521		
23/7, 12^h 57^m	1·026	*0·00	−0·074	30/7, 9^h 01^m	1·651	*167·90	0·533
3 37	1·147	2·67	+0·047	1 15	1·654		
24/7, 9^h 28^m	1·289	20·52	0·189	4 16	1·660		
1 03	1·300	24·10	0·200	31/7, 9^h 54^m	1·671	191·94	0·572
4 23	1·307	27·43	0·207	12 44	1·672		
26/7, 9^h 08^m	1·398	68·18	0·298	4 03	1·672		
12 17	1·409	71·33	0·309	2/8, 9^h 04^m	1·689	239·95	0·592
3 58	1·417	75·02	0·317	1 27	1·692		
27/7, 9^h 08^m	1·433	95·71	0·337	4 11	1·695		
12 38	1·437			5/8, 1^h 42^m	1·727	338·63	0·627
4 13	1·441			5 27	1·727		

* Adjusted anew. † Total twist $\psi_e-(\psi_b)$=180°, twist of steel positive.
‡ Total twist $-\psi_e+(+\psi_b)$=180°, twist of steel, negative.

TABLE 34.—APPARATUS III.

R=370^{cm}; L=26^{cm}; $l<0{\cdot}2^{cm}$. Rods: No. 51, soft, $\psi=-180°$; No. 52, annealed 450°, $\psi=+180°$. 2ρ=0·082.^{cm}

Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$	Date.	$\phi\times10^3$	h_0	$\phi_0\times10^3$
20/8, 12^h 35^m	*	0·00	*	25/8, 9^h 05^m	0·581	92·80	0·027
12 50	0·291	0·25	−0·004	7 01	0·568		
6 44	0·306	6·15	+0·011	26/8, 9^h 10^m	0·568	115·40	0·014
21/8, 9^h 07^m	0·314	20·53	0·019	4 08	0·556		
5 00	0·311	28·42	0·016	27/8, 9^h 10^m	0·548	144·13	−0·009
21/8, 5^h 15^m	†	0·00	†	7 36	0·530		
5 25	0·546	0·16	−0·002	28/8, 9^h 20^m	0·530	164·87	−0·023
7 08	0·551	1·88	+0·003	6 55	0·520		
22/8, 9^h 57^m	0·556	16·70	0·008	29/8, 10^h 12^m	0·515	188·99	−0·037
6 54	0·561	25·65	0·013	6 17	0·507		
23/8, 9^h 08^m	0·561	39·88	0·013	30/8, 9^h 11^m	0·505	207·93	−0·043
5 37	0·561	48·36	0·013				
24/8, 9^h 18^m	0·581	68·00	0·033				
5 13	0·581						

* Adjusted $\tau-b-f$. † Re-adjusted $\tau+b+f$.

We have not yet made the tubular apparatus as sensitive in its indications as is the bifilar. The results are nevertheless sufficiently sharp and pronounced and are cited here for their important bearing in the inferences to be drawn for steel. Fine glass tube is to be preferred to brass.

Discussion.

Viscosity and temper.—1. The results of tables 1 to 26 may be discussed in two ways: We may either accept some definite and applicable law like that of Weber or of Kohlrausch, and calculate the mean constants for each set of results; or we may construct them graphically and then calculate the coördinates of the mean curve for each set. The latter is decidedly the better way, because it is less arbitrary and more convenient. In table 33 the mean results in question are thus summarized. The first three columns indicate the tables from which in each case the selections are made, the rods selected, and their tempers. The remaining columns contain the differences of viscous detorsion, φ_0, in radians per centimeter of length of the bifilar, one of the wires of which is invariably glass-hard, the other annealed as stated. φ_0 is arbitrarily fixed at zero, for one hour after a twist of $+180°$ and $-180°$ has been imparted to the soft and hard wire, respectively.

Table 33.—*Digest of the mean results. Tables* 1 *to* 26.

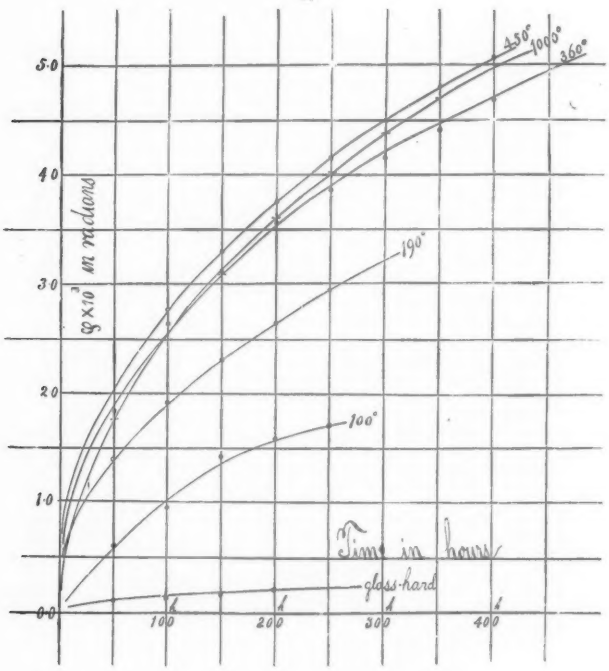
Table No.	Rods Nos.	Annealed at	$\phi_0 \times 10^3$ in radians per centimeter of length at							
			50^h	100^h	150^h	200^h	250^h	300^h	350^h	400^h
1, 2	1, 2 47, 43	20°, ∞^h (glass-h'd)	0·08	0·11	0·15	0·19	....	....	....	....
5A, 6A, 7, 8	3, 4, 5, 6, 7, 8 9, 10, 43, 44, 45, 46	100°, 10^h	0·59	0·96	1·41	1·58	1·71	...	....	....
10, 13, 13A, 14	11, 12, 13, 14 15, 16, 19, 20	190°, 1^h	1·38	1·89	2·27	2·63	2·95	...	....	....
16, 18	17, 18 21, 22	360°, 1^h	1·80	2·61	3·13	3·53	3·84	4·14	4·42	4·70
19, 20	23, 24 25, 26	450°, 1^h	2·01	2·76	3·31	3·75	4·14	4·49	4·80	5·07
23, 24, 25, 26	27, 28, 29 30, 31, 32 33, 34	1000°	1·76	2·51	3·10	3·61	4·04	4·40	4·67	....

All radii identically $2\rho = 0{\cdot}082^{cm}$. Like signs of ϕ and of ψ refer to the same angular direction.

The results of table 33 are graphically constructed in figure 3, time in hours as abscissa, difference of angular detorsion φ_0, in radians, as ordinate.

Table 23 and figure 3 lead to this curiously remarkable result: If we abstract for the moment from the states of temper extreme hard and extreme soft, *the viscosity of steel decreases in proportion as the hardness of the metal increases.* We call to mind

here that the torsion imparted was not sufficiently large to produce marked permanent set. If we express its intensity by



$(0{\cdot}4E)\frac{\pi\rho^4}{2L}\psi$, and introduce the constants of the apparatus

$$\psi=\pi,\ L=30^{cm},\ 2\rho=0{\cdot}082^{cm},$$

we find that the moment of the applied torsion couple did not exceed 0·5 kg. on centimeter of arm. (Cf. remark on stress value, p. 30.) If following Sir William Thomson,* we agree that "the molecular friction in elastic solids may properly be called viscosity of solids," then our deduction may be stated, *the molecular friction in case of steel is greater in proportion as the metal is softer.*† Examples of such relations in divers substances are not unknown. Hard steel as regards viscosity and

* Thomson: l. c., or Thomson and Tait, Natural Philos., II, p. 303, 1883. Our present conception of the viscosity of liquids, as well as the hypotheticated proportionality of frictional resistance and velocity were introduced by Newton (Principia, L. II, Sect. ix. "resistentia quæ oritur ex defectu lubricitatis").

† Degrees of thermo-electric hardness are here specially in place. Cf. U. S. Geolog. Survey, Bull. 14, p. 65.

hardness may be typified by sealing-wax; soft steel by tallow.* Nevertheless the continuous variations of these properties exhibited by steel is as unique as it is striking. Indeed we felt diffidence in reporting this result and have taken pains to substantiate it.

The motion of the bifilar body of the above apparatus can be interpreted from two standpoints: Either it is due to the torsional couple and the result of viscous yielding of the harder wire relatively to the softer; or it may be due to the bifilar and flexural couple and is then the result of viscous yielding of the softer wire relatively to the harder (xxxii, p. 466). But the bifilar and flexural couples have been proved to be zero and to produce a zero effect. Hence the inference above italicized is alone admissible. Again, in the bifilar apparatus where steel is twisted against glass (table 28) the soft steel is demonstrably more viscous than glass. Hard steel, as shown by its behavior with the same fibre, is less viscous than soft steel. We do not wish to say that it is less viscous than glass because the sectional area of the latter fiber is larger. Again, in table 31, which contains the data obtained with the tubular apparatus, soft steel yields viscously at about the same rate as the brass tube of more than *four* times the sectional area of the steel wire. Hard steel under the same circumstances yields at a very much greater rate than brass.

Our results for degrees of hardness higher than "Annealed 100°, 10^h" are to be regarded incomplete because of the magnetic importance of those degrees. As steel passes in hardness from "Annealed 450°" to "Annealed 1000°" (soft), it probably marches through pronounced maximum viscosity. This result is pretty clearly indicated by table 33 and figure 3. Here also the results are to be regarded incomplete because of the magnetic importance of the (soft) degrees of hardness in question. Our methods of annealing between 500° and 1000° are not as yet satisfactory.

2. If we compare the results of table 33 or of fig. 3 with the known thermo-electric behavior† of steel wires, we detect a very striking similarity in contour and position of corresponding members of the viscous and thermo-electric families of curves. Both phenomena practically subside in the first phase of annealing; the effect of temperature becomes rapidly less as higher degrees are approached.

3. The relations between hardness and viscosity here encountered may perhaps be conceived somewhat as follows: Suppose stress to be so distributed in a solid that its applica-

*These examples (tallow, sealing wax) are given by Maxwell: Heat, p. 296, Appleton, N. Y., 1883.

† U. S. Geol. Survey, Bull. 14, pp. 54, 55.

tion at any interface is nowhere sufficient to produce rupture. Then that property of a solid in virtue of which it resists very small forces (zero-forces) acting through very great intervals of time (∞-times) may be termed the viscosity of the solid. That property in virtue of which it resists the action of very large forces (∞-forces relatively) acting through zero-time may be termed the hardness of the solid. Since the application of forces in such a way as accurately to meet either of these cases is rare, we have in most practical instances mixtures of viscous resistances and of hardness to encounter. We may reasonably conceive that in the case of viscous motion the molecules slide into each other or even partially through each other per interchange of atoms, so that the molecular configuration is being continually reconstructed; that in the other case (hardness) the molecules are urged over and across each other and that therefore the intensity of cohesion is in this case more or less thoroughly impaired. The interpenetration of the molecules of a viscous substance is necessarily favored by temperature. Hence we infer the experimental result that the viscous influence of temperature is marked. If Clausius's theory of electrolysis be correct, then a certain instability or imperfect uniformity in the molecular structure of solids follows at once from the fact that many solids, notably glass,* may be electrolyzed even at moderately high temperatures (300°).

4. The stored torsional stress imparts a strain to the solid. Viscous detorsion therefore is accompanied by a residual phenomenon. The observed deformation will continue until the applied tendency to change of form is reduced in value to the evoked and increasing tendency against change of form. If the applied stress be removed, the reciprocating stress becomes apparent and produces viscous effects of its own kind, as Kohlrausch has shown. The result has many magnetic and electrical analogies, among which the phenomenon of residual static charge is most obvious. In the tubular apparatus (table 31), the residual deformation of the preceding twist may be superimposed on the deformation immediately in progress. Whether the two residual phenomena here annul each other so that the primary detorsion is alone exhibited remains to be seen.

In liquids there is no such reaction unless it be the reciprocating force of galvanic polarization. In polarization, however, the mechanism is of an obviously chemical kind. In solids it is believed to be not chemical.

Sectional areas of bifilar wires.—The essential peculiarity of the bifilar apparatus is this, that the two wires are twisted by

* Warburg: Wied. Ann., xxi, p. 622, 1884. Literary notes are there given. Warburg is able to replace $\frac{1}{3}$ of the sodium of glass by sodium of the anode.

identical couples.* The absolute value of these couples during the experiment remains constant to 2 or 3 per cent. If the sectional areas of the wires be identical our apparatus leads to results which come very close to Newton's definition of viscosity. Newton suggested that the internal friction of liquids is *cæt. par.* directly proportional to the difference of velocity between nearly contiguous surfaces. In the bifilar apparatus the torsional viscosities of two substances are equal if for identical strains and equal sectional areas torsional change of form occurs at like rates per unit of length. This is the condition of rest or zero-motion of the suspended body.

We do not at present wish to do more than advert to an important deduction here: it is obvious that if the sections of the wires be so chosen that the motion of the bifilar body is zero, the viscosity of the wires must be inversely related to those sections. This principle apparently enables us to arrange solids in a scale of viscosity. We may formulate it approximately thus:

Consider an elementary ring of either wire, whose height is dz and whose right sectional area is $2\pi r dr$. Let df be the amount of tangential force uniformly distributed over this area. At the time t let the velocity of the upper surface relatively to the lower be cr, where c is a time-function and *cæt. par.* a characteristic of the viscosity of the wire. Then if μ_t be the coefficient of viscosity at the time t we have

$$df = \mu_t \frac{cr 2\pi r dr}{dz} = 2\pi\mu_t \frac{cr^2}{dz} dr$$

If we multiply by r and then integrate between zero and ρ (thickness $= 2\rho$), the numerical result is the part of the impressed torsional couple which corresponds to the length dz. A similar integral holds for the other wire, to distinguish which it is merely necessary to accentuate f, μ_t, c, r, ρ. The sum of the two integrals is zero. If, moreover, we put $c=c'$ in view of the state of rest of the bifilar body, we find that the viscosities (μ_t, μ'_t) of the two substances (wires) are to each other inversely as the squares of the respective sectional areas by which the motion of the bifilar suspension is annulled.

Unfortunately the problem is much more complex than it here appears. The dependence of torsional deformation on time in case of a single wire is obviously related to the character of the molecule. When two different substances in wire form are twisted bifilarly against each other, the effect will

* Many years ago we compared the longitudinal resilience of hard and soft steel by fastening one end of thin wires in a vise and bending them with a weight applied at the other. We found but insignificant differences. Hence the stored torsions of two steel wires, hard and soft, produced by equal couples are *cæt. par.* of equal angular value.

rarely be such that the torsional yieldings continually equalize each other, no matter what relations of section may be chosen. The motion-curve of the bifilar-suspension will show maxima or even points of circumflexion, such as have been actually encountered in tables 28, 29, 29A, and the definition of relative viscosities of the two wires will become correspondingly involved.

Again, μ_t for solids is not merely a function of time but very essentially a function of stress. Above we show (xxxii, p. 452) how by simply adjusting the lengths of the bifilar wires, viscosities may be compared at a given temperature, as time-functions with identical values of the parameters stress, strain (sectional area). We do not believe that viscous detorsion in this full relation has ever been rigidly investigated. The results would lead to families of curves.

Given a quadrifilar arrangement of four viscously identical wires. Let the twist ψ_{12} be stored between any two of them and then let the twist $\psi_{12'34}$ be additionally stored between these two as one, and the third and fourth wire as one. Such a device enables us in the above way to study viscosity in its simple dependence on strain, for all values of stress. We have not, after some searching, been able to find definite evidence of a viscous strain-effect.

Viscosity and strain.—1. When we commenced the present research a comparison of the viscosity of glass and steel appeared desirable. In tables 27 and 28 such comparisons have been attempted, though we regret that our available time has not permitted us to pursue them further. In table 27, the sectional area of glass fiber is less than that of steel wire; nevertheless the viscous yielding of the fiber is so much more rapid than that of the wire, that we may reasonably infer degrees of viscosity of the same order in the two substances. In table 28, the sectional area of glass exceeds that of steel. Hence these data prove that the torsional viscosity of annealed steel is greater than that of glass. The viscosity of hard steel during the first ten hours of detorsion is certainly very much greater than that of glass. During the remainder of the time it is decidedly less. The curve passes through a maximum for which point the rates of viscous detorsion of glass and of glass-hard steel exactly coincide. Since the sectional area of glass is greater, we safely infer that the viscosity of glass is not uniformly greater than that of glass-hard steel. It is well to call to mind, however, that the sum of the torsions is here only $\psi_s+\psi_g=90°$. Moreover, since for equal couples and dimensions $E_g\psi_g=E_s\psi_s$, where E is Young's modulus* of resilience for

* To obtain an estimate it is sufficient to accept the same ratio of modulus of torsion to modulus of longitudinal resilience for each case. Poisson's ratios for glass and steel are about as 26 to 30.

glass and for steel respectively and ϕ the corresponding torsion; and since $E_g/E_s=1/3$ approximately, it appears that $\phi_g=3\phi_s$ nearly. Hence for equal stresses, strains are thoroughly unequal, and in the same measure are these comparisons not thoroughly just. Cf. xxxii, p. 30.

2. A similarly important desideratum is the comparison of the viscosities of steel and of iron. In tables 29, 29A and 30 such comparisons are made, though further results are not superfluous. It appears distinctly that during the first five or ten hours of detorsion the viscosity of iron is in a strikingly pronounced manner less than that of steel. As detorsion continues the viscosity of soft iron continually remains below that of steel, whereas the viscosity of drawn iron grows temporarily greater than steel but finally reaches the same value. In this case the motion-curve passes through an exceedingly sharp maximum, at which the viscous yielding of iron and of steel occurs at like rates. Having exhibited greater viscosity in drawn iron it finally, per circumflexion, merges into a horizontal asymptote, which probably indicates subsidence of motion in each wire. These unexpected results show that the viscosity of steel is not uniformly greater than that of iron. Obviously glass-hard steel for the given stress is very much less viscous than iron.

The sum of the twists is here nominally $\phi_s-(-\phi_i)=360°$. Particularly in the case of soft iron its efficient value is very decidedly less, however. The applied torsion carries the iron wire much beyond the limits of elasticity; and so much of the stress vanishes instanter that the "after-action" subsides within relatively small limits. The viscosity of (soft) iron is either less or greater than that of hard steel according as the applied torsional stress surpasses or falls below a certain critical value. This result again shows the importance of stress-measurement, as a means of coördinating the lingering of purely viscous deformation and the instantaneous (?) deformation.

In the above results the curvature of the (absolute) motion curve for a *single* wire increases uniformly from hard steel to soft steel; increases, moreover, from soft steel to iron. Curvature is greater in the glass curve than in hard steel curves. So far as we have observed (steel, iron, glass) viscous deformation occurs more nearly at uniform rates (linearly) in proportion as hardness is greater. Curvatures for early time are meant, the later parts of curves being asymptotes.

3. The remarks just made on the viscosities of glass and iron suggest this plausible inference: if glass and steel be alike subjected to a stated process of quenching, and if after the operation has been performed glass be found to have retained a very high intensity of strain (Rupert's drop), then, *a fortiori*, steel,

the substance of greater viscosity, must have retained a similarly high intensity of strain. This reasoning, however, is incomplete and must be approached with caution. We pointed out* that the low degrees of thermal conductivity possessed by glass were favorable to the retention of strain. We also remarked† that the occurrence of Gore's phenomenon of sudden expansion at red heat distinguished iron and steel from all other metals, and that in spite of relatively good thermal conductivity, iron and steel possessed virtually all the favorable conditions of glass for retaining strain. Whether differences of viscosity are sufficient to account for the unlikeness of behavior during quenching we are unable to say. It will be necessary to compare iron and steel at higher than ordinary temperature and also under greater values of applied stress than was easily feasible in the above experiments. In other words, iron and soft steel are nearly equally viscous for small values of stress. After stress exceeds a certain intensity, the permanent set suddenly imparted to iron is enormously great as compared with steel. Similar relations are true for soft steel when compared with hard steel. It is this class of "sudden" phenomena which come into play during quenching. The primary effect of quenching steel is chemical hardness. Strains are retained in the steel so modified, just as they are in glass: whereas in soft steel or soft iron the result would be permanent set. The occurrence of sudden and gradual deformation in a single substance suggests that ordinary *static* friction is probably a viscous phenomenon.

We add in passing that the observed inefficiency of temperatures less than 200° in producing marked viscous deformation in a Rupert's drop proves that mere interference of thermal expansion with the conditions of strain cannot be the primary cause of its variations; that strain variations essentially depend on diminished viscosity.

We also add in passing that the importance of strain as associated with glass-hardness is emphasized by the mass-constants of the cast-irons. The densities of these metals‡ range between the maximum of ca. 7·6 for white cast iron and the minimum of ca. 6·9 for gray cast iron. Hence density increases in marked degree in proportion as total carbon is more and more nearly combined. Quite the reverse of this is true for steel where density decidedly decreases as total carbon is more and more nearly combined. This discrepancy we interpreted as a strain of dilitation and carefully compared it with the analogous behavior of glass in our earlier papers

* This Journal, xxxi, p. 451, 1886. † Bull. 14, p. 99.

‡ Cf. Bloxham's Chemistry, p. 342, Lea, Philad., 1873. Bull. 14, pp. 76, 77.

We add finally the following data from the elastics of glass and of steel. The æolotropic expansion produced by quenching glass or steel we showed elsewhere* to amount to 0·005. The volume resilience of glass and of steel, according to Professor Everett's measurements,† is 4×10^{11} and 2×10^{12} respectively. Hence if per square centimeter p be the stress-value for the given expansion, we find aproximately $p=10\times10^{9}$ dynes for steel and 2×10^{9} dynes for glass. Now per square centimeter the tenacity of steel is 8×10^{9} dynes; the tenacity of glass $0{\cdot}6\times10^{9}$ dynes. The approximate ratio of stress to tenacity is therefore estimated at 1·3 for steel and 3·3 for glass. This shows that in both cases stress and tenacity are of the same order; that stress is in excess; that but for the peculiarly favorable, symmetrically arched structure of the quenched globule, rupture would ensue in glass certainly; probably also in steel. This accords with the explosive tendency of a P. R. drop and with the less pronounced liability of steel to crack on quenching.‡ If therefore quenched glass and quenched steel are under mean stress intensities of several thousand atmospheres, then in discussing the corresponding viscous properties they must be brought into relation with these high values of peculiar stress.

Magnetic relations.—1. If again we abstract from the extreme states of hardness, we find that both the viscosity and the moment of linear magnetization per unit of mass, of a permanently saturated steel rod, increase in marked degree from hard to soft. This is a singularly striking result, inasmuch as the conditions of magnetic stability (following Hopkinson we shall call them coercive force), conditions which at first sight we would be inclined to associate with viscosity, decrease as viscosity increases. Hence permanently saturated linear magnetic intensity and viscosity on the one hand, magnetic stability or coercive force and hardness on the other, seem to belong together.

2. The minimum of permanent linear intensity of saturated steel rods has no viscous equivalent; but we have not yet studied the viscosity of extremes of hard steel minutely, nor have we as yet sufficiently sharp data for the magnetization of very long rods (length/diameter$>$100) in its relation to temper. In the extreme soft region, on the other hand, the occurrence

* This Journal, xxxii, pp. 190, 191, 1866. By æolotropic expansion we refer to the part of the total expansion which produces explosiveness and the polariscopic phenomenon.

† Everett: Phil. Trans, p. 369, 1866. The above numbers are rounded from Everett's values.

‡ Mr. J. M. Batchelder has just communicated to us his interesting results (Journal Franklin Inst., (3) viii, p. 133, 1844), in which of twelve massive pieces of quenched steel, eight subsequently cracked and one actually exploded.

of a unique maximum of magnetization seems certainly to be coincident with the occurrence of maximum viscosity. The magnetic maximum so far as our results go is apparently much more clearly pronounced than the viscous maximum. We remark in general that as the ratio of length to diameter increases, the minimum of permanent magnetization shows a tendency to move from soft to hard. Furthermore, it is proved that the permanent magnetization of soft rods is greater in proportion as they are more and more nearly linear.* Hence as our march approaches the linear limit we observe an unmistakable tendency toward more detailed similarity between the variations of the magnetic and the viscous properties of steel.

Mr. Hopkinson† in his memoir on the magnetization of iron introduces a definition of coercive force, defining it as "that reversed magnetic force which just suffices to reduce the induction to nothing after the material has been subjected temporarily to very great magnetizing force." There is a slight objection to this definition, inasmuch as it introduces a somewhat vaguely complex state of zero-magnetization.‡ But the feature in question is as hard to improve as the definition is valuable. Mr. Hopkinson's extensive experiments show that coercive force is invariably increased by hardness. Together with others we have proved that hard steel is alike well adapted to withstand the influence of percussion.

3. These general relations between viscosity and maximum permanent linear intensity observed for steel are sustained by iron. According to data contained in a paper of the lamented Dr. L. M. Cheesman§ the permanent magnetization of drawn iron exceeds that of soft iron. The magnetic intensity of permanently saturated drawn iron is comparable with that of soft steel and quite equal to that of hard steel. More recently and even more elaborately Ewing has discussed the subject. He finds "in the absence of mechanical or other disturbance, soft iron is far more retentive than either hard iron or steel," an exceedingly remarkable result.‖ Our experiments show that the intensity of applied stress is an important factor in determining the viscous behavior of iron; that for moderate

* Bull. 14, pp. 240 to 143.

† Hopkinson: Phil. Trans., ii, 463, 1885.

‡ The unmagnetic state, though dependent on the details of the process of tempering, is a distinct magnetic state. Similarly we may regard the saturated magnetic state, though allowance must here be made for the occurrence of cyclic magnetization, a phenomenon suggested by Fromme (Wied. Ann., iv, p. 89, 1878) and (Wied. Ann., xiv, p. 308, 1881), concisely interpreted by Warburg (Wied. Ann., xiii, p. 141, 1881) and which Ewing (Phil. Trans., ii, p. 545, 1885) has recently discussed generically under the name of "hysteresis."

§ Cheesman: This Journal, xxiv, p. 183, 1882. Lengths 100 diameters and less.

‖ Ewing: l. c., p. 541.

stress values it *ultimately* approaches very closely to or even exceeds the maximum viscosity of steel; that it is much greater than the viscosity of hard steel.

4. With these accordances before us, we may venture a final suggestion. The viscosity of iron increases with great rapidity with the amount of deformation. For a certain interval of (low) values of applied torsional stress it even exceeds the maximum viscosity of steel. Hence if there be an inherent bearing of viscosity on retentiveness, there is given us in iron a condition of magnetic instability: if relatively to the (decreasing) amount of deformation or of magnetization viscosity decreases rapidly, then a mere shock may at once deprive the magnet of the whole of its induction. The retarded curvature of the steel curves (tables 1 to 26) does not invalidate this inference, since retardation is here an expression of the fact that the absolute amount of change of form for each rod decreases as time increases.

We do not wish to push these inquiries into further detail at present because we have experiments with iron now in progress. Nevertheless we invite the reader to peruse for comparison Mr. Ewing's magnetic results as summarized by him, l. c., pp. 562, 563.

Conclusion.—Among the chief results of this paper is the light thrown on the crucial importance of the physical changes which steel undergoes during annealing at high temperatures, i. e. when subjected to the action of temperatures between 500° and 1000°. It is within this interval that a variety of nearly coincident phenomena occur: Gore's* sudden volume expansion; Tait's† sinuously broken thermoelectric diagram-line; we infer an irregular behavior of electrical resistance; Gore-Baur's‡ sudden disappearance of magnetic quality; the passage of carbon from uncombined to combined; Jean's§ critical cementation temperature. Furthermore, Chernoff-Barus'‖ sudden appearance of hardness in quenched steel, Fromme's¶ maximum density, Chwolson's** minimum resistance, our own unique maximum of magnetization†† and probable maximum of viscosity, are all referred to this interval, approximately to the

* Gore: Proc. Roy. Soc., xvii, p. 260, 1869.

† Tait: Trans. Roy. Soc., Edinburgh, xxvii, 1872–73, p. 125.

‡ Gore: Phil. Mag., IV. xxxviii, p. 59, 1869; Baur. Wied. Ann., xi, p. 408, 1880; Ibid., xl, p. 170, 1870.

§ Jeans: "Steel, its history, etc." London, Spon, 1880.

‖ Chernoff: Vortrag. geb. in der Russ. techn. Ges., April and Mai, 1878. Barus: Wied. Ann., vii, p. 405, 1879.

¶ Fromme: Wied. Ann., viii, p. 354, 1879. We were unable to find Fromme's maximum: but we shall search again. All these results are crucially dependent on the method of annealing, as stated in the text.

** Chwolson: Carl's Rep., xiv, p. 26, 1878.

†† Barus and Strouhal: U. S. Geol. Survey, Bull. 14, pp. 145, 198.

same temperature. To determine the interdependence of these important phenomena it is obviously first necessary to devise methods of operating on steel adapted to the interval in question. In other words, our introductory problem is the annealing of steel without oxidation and without carburation, at measured (high) temperatures, during stated times. It is in this direction that we propose to have our investigation proceed.

Washington-Prague, September, 1886.

ART. IV.—*The nature and origin of Lithophysæ and the lamination of acid lavas;** by JOSEPH P. IDDINGS.

THE Yellowstone National Park with its thousands of square miles of rhyolitic lavas, presents a splendid field for the study of the various forms of structure and crystallization assumed by acid lavas in cooling. And it is the investigation of these phenomena, observed while prosecuting the work of the U. S. Geological Survey within this region in charge of Mr. Arnold Hague, that has furnished the writer with the data upon which the conclusions here stated are based.

Among the many phases of crystallization so richly developed in the rhyolitic obsidian forming Obsidian Cliff, the most characteristic is the spherulitic, producing spherulites from microscopic dimensions to several inches in diameter. They are crystalline bodies with a radially fibrous structure, which is often accompanied by a banding in concentric layers of different color and density. In thin section under the microscope they are seen to be composed of sectors of fibers, which between crossed nicols do not extinguish the light parallel to the length of the fibers which would produce a distinct shadow-cross, but at different angles, making many rays of shadow, which in the smallest spherulites frequently approach the form of a cross. These spherulites have been traced through gradations of microstructure to groups of granophyre feldspars of extreme minuteness, which appear to be composed of intergrown quartz and acid feldspar, and enclose trichites and microlites which also occur in the spherulites, so that the mineral composition of the spherulites is most probably quartz, acid feldspar and trichites of magnetite with augitic microlites. Chemical analyses of the spherulites and the obsidian in which they occur show that the two are identical, and that a spherulite is only a particular form of crystallization of the once molten glass. The largest spherulites have an earthy texture and in thin section

* Extract from article to appear in the Seventh Annual Report of the Director of the U. S. Geological Survey; published by permission of the Director.

are seen to be made up of jointed fibers composed of microscopic feldspar crystals; between these fibers are scales of tridymite with scattered grains of magnetite and microlites, besides innumerable gas cavities. Frequently the tridymite is aggregated into pellets which enclose several feldspar fibers, leaving quite porous spaces between. The centers of these larger spherulites often have the same structure as the smaller spherulites, and the fibers of one appear to be continued into the other, but to have formed under somewhat different conditions, since the cementing mineral is quartz in one case and tridymite in the other.

In the porous portions of the large spherulites, intergrown with the feldspar fibers and appearing to be of later crystallization is an occasional individual of yellow iron-olivine or fayalite. So that the association of minerals here developed, tridymite, acid feldspar and fayalite, is quite an uncommon one for an igneous rock.

The spherulites are frequently so porous as to be hollow in places. Sometimes a large cavity is situated in one side of a radially fibrous spherulite. In this case the fibers project into the cavity and are distinctly visible without the aid of a magnifying lens, the pellets of tridymite being also recognizable. The cavity may be near the circumference of the spherulite and adjoining the enclosing matrix, or lie nearer the center leaving a dense periphery or crust like the rind of a melon. This is the more usual form. Very often the central portion appears to have shrunken and cracked apart, the surface markings on the opposite sides of the gaping cracks corresponding exactly, and showing that the walls had once been united in a continuous mass. Another variety has the cavities in concentric layers, with delicate partition walls between them forming thin concentric shells. When these have been developed in a lava to which there is a laminated structure, marked by layers of microlites and other forms of crystallization, the concentric shells of the hollow spherulites are traversed by thin layers of crystals in continuance of the lamination in the matrix.

The large hollow spherulites are generally hemispherical, and the concentric shells and cavities produce very beautiful structures, which when broken across present roselike centers surrounded by delicate encircling rings. These forms are especially characteristic of the lithoidal portion of the obsidian flow at Obsidian Cliff and are the typical structures which have been called *lithophysæ* by von Richthofen* because they appear to have been inflated by expanding gas, the word being derived

* "Studien aus den ungarisch-siebenbürgischen Trachytgebirgen." Jahrb. d. k. k. geol. Reichsanst., 1860, p. 180. Also, The Natural System of Volcanic Rocks, San Francisco, 1868, p. 14.

from λιθος, a stone, and φυσα, a bubble. The term applies equally well to all the concentrically chambered varieties, and may be extended to all forms of hollow spherulites.

The substance of the lithophysæ occurring at Obsidian Cliff is usually light colored and distinctly crystalline with a beautiful frosted appearance. It is made up of minute crystals in well developed forms, which in places attain a considerable size, from 1 to 2^{mm}. The minerals recognized are: quartz and tridymite, feldspar, fayalite and magnetite. The feldspar in some cases has the crystal habit of adular, and in others is in thin tabular crystals with the simplest combination of faces, flattened parallel to the base. They appear to hold an anomalous mineralogical position, being soda-orthoclase in composition (Al, Or,) and having the crystallographic habit of sanidin but an asymmetric optical character. The fayalite was described in this Journal for July, 1885. It appears to be identical in crystal form with the mineral occurring in the lithophysæ of the obsidian of Cerro de las Navajas which was measured by Gustav Rose,* and determined to be olivine in 1827. The angles and habit of the crystals figured by him are almost identical with those obtained by Mr. S. L. Penfield from the fayalite at Obsidian Cliff, and it is highly probable that the mineral determined by Rose is also an iron olivine or fayalite. The magnetite occurs as microscopic grains and crystals.

Since the first application of the term lithophysæ to these hollow, chambered structures, and the expression of von Richthofen's views as to their probable mode of formation, petrographers have discussed their origin, wandering more or less from the position first held by von Richthofen, and it is with the belief that the material on which these recent observations have been made furnishes better ground on which to build a theory of the origin of lithophysæ than any heretofore studied, that the writer has endeavored to throw some light upon so obscure a subject.

It was von Richthofen's† opinion, expressed in the year 1860, that the concentric shells were produced while the rock was in a molten or plastic condition, by the expansion of gas bubbles which were successively disengaged from certain portions within the mass, in consequence of the diminution of pressure accompanying the eruption of the lava. The gases which were in large part aqueous, having most likely been absorbed, thereby forming a hydrated glass. He considered lithophysæ as quite distinct from spherulites, and suggested that only careful chemical analyses would settle their true nature.

* "Ueber den sogenannten krystallisirten Obsidian." Pogg. Ann., 1827, Band 10, pp. 323–326.

† Loc. cit.

Six years later Dr. Joseph Szabó* expressed the opinion that lithophysæ were only a stage in the mechanical and chemical alteration of spherulites, the bases being removed by chemical means, the insoluble particles mechanically, and silica being concentrated in the cavity.

In the same year Karl von Hauer† published the analyses of four rhyolites and the lithophysæ contained in them, which showed that the chemical composition of the lithophysæ and rhyolites were the same. He therefore held to von Richthofen's view that the cavities were the result of expanding gases, but thought that these gases had no metamorphosing action on the groundmass of the rock. Later on Justus Roth‡ adopted Szabó's views and recently repeated them in the second volume of his Algemeine und Chemische Geologie.

Dr. Ferdinand Zirkel§ in 1876 described certain spherulites in the rocks from Shoshone Mesa, Idaho, which "have developed by decomposition a hollow concentric layer structure." These he considered the same as the lithophysæ of von Richthofen and that they in like manner were only the result of chemical alteration.

Dr. Ch. E. Weiss‖ in 1877 suggested that the cavities of hollow spherulites play the same rôle as a solid body around which a spherulite forms, that the chambered spherulites were caused by several gas bubbles being near together when the spherulites were developed.

Mr. Grenville A. J. Cole,¶ in a paper recently published, concluded that the hollows are due to the decomposition of solid spherulites by chemical agents, the material having been carried out through cracks in the rocks.

Mr. C. A. Tenne,** in describing the lithophysæ in the obsidian of Cerro de las Navajas, Mexico, says that the substance of the lithophysæ must be devitrified obsidian, and gives chemical analyses which show that both have the same chemical composition.

Mr. Whitman Cross,†† in a paper "On the Occurrence of Topaz and Garnet in Lithophysæ of Rhyolite" points out the fact that these minerals are not of secondary formation in the cavities, but primary, "produced by sublimation or crystallization from

* "Die Trachyte und Rhyolite der Umgebung von Tokaj." Jahrb. d. k. k. geol. R.-anst., 1886, p. 89.

† "Die Gesteine mit Lithophysenbildungen von Telki-Banya in Ungarn." Verhandl. d. k. k. geol., R.-anst., 1886, p. 98.

‡ "Beiträge zur Petrographie der plutonischen Gesteine, 1869, p. 168.

§ "Microscopical Petrography," Washington, 1876, p. 212.

‖ "Quarz porphyren aus Thüringen," Zeitschr. Deutsch. geol. Gesellsch., 1877, xxix, p. 418.

¶ "On Hollow Spherulites," etc. Quart. Journ. Geol. Soc., May, 1885.

** Zeitschr. Deutsch. geol. Gesellsch., 1885, p. 610.

†† This Journal, June, 1886.

presumably heated solutions, contemporaneous or nearly so with the final consolidation of the rock. The lithophysal cavities seem plainly caused by the expansive tendency of confined gases or vapors, while the shrinkage cracks in the walls and white masses of the Nathrop rock suggest the former presence of moisture."

It is seen from the foregoing that two distinct views of the origin of the cavities within the lithophysæ have been taken; one, that the hollows were of primary origin, formed while the lava was still plastic, and were due to enclosed gases or vapors. Among those who held this opinion some considered the lithophysæ as wholly distinct from spherulites, while others thought them simply hollow varieties. The second view was that the hollows had been produced in solid spherulites by chemical decomposition and alteration and were subsequent to the solidification of the lavas in which they are found. With the latter view, which may apply to some hollow spherulites in particular cases of decomposed rocks, the lithophysæ in the obsidian from the Yellowstone National Park have nothing to do. The extreme freshness of the whole rock and the absence of secondary alteration prevents the confusion which arises when these hollow forms are associated with decomposition products or subsequent metamorphism, as is the case with many ancient lavas, or even with recent ones which have been attacked by solfataric or hot spring agencies.

What, then, from a study of this exceptionally fresh and beautiful material, seems to be the most probable origin of lithophysæ, and how nearly the writer's views accord with those of von Richthofen will appear from the following considerations.

The association of fayalite, an iron-olivine, with abundant quartz and tridymite, and acid feldspar in a highly siliceous, igneous rock, containing less than two per cent of iron oxide, is quite contrary to ordinary experience and is not in accord with the generally accepted laws which appear to govern the crystallization of igneous magmas. Moreover, two of the accompanying minerals, prismatic quartz and acid feldspar, have not been reproduced artificially by simple igneous fusion, as has been demonstrated by the repeated experiments of MM. Fouqué and Michel-Lévy,* who, though successful in obtaining most of the minerals found in igneous rocks, have failed to reproduce by dry fusion quartz, orthoclase and albite in forms similar to those in which they are found in acid eruptive rocks.

On the other hand quartz, tridymite, orthoclase and albite have all been obtained artificially by aqueo-igneous processes, on heating their chemical elements in the presence of water in

* "Synthèse des Mineraux et des Roches," Paris, 1882.

sealed tubes. The experiments of MM. Friedel and Sarasin,* upon the reproduction of orthoclase and albite are especially applicable to the case of lithophysæ. Among the forms of orthoclase produced was that of adular, also observed in the hollow spherulites. Along with orthoclase they obtained quartz and at higher temperatures tridymite. Other experiments, especially those of K. von Crustschoff,† have established the same relation between quartz and tridymite when formed in closed tubes. Tridymite being produced at a higher temperature than quartz, and frequently both occurring together within the same closed tube.

Magnesia olivine and magnetite have each been reproduced by aqueo-igneous methods, and fayalite is a common product of puddling furnaces. So that the group of minerals composing the lithophysæ in this obsidian are such as may be formed through aqueo-igneous processes.

The well-known experiments of Daubrée,‡ on the effect of superheated steam on a glass tube, have a special bearing on the question under consideration. The glass used by Daubrée differed in chemical composition from that of the obsidian, but the general nature of the results bears a striking similarity to many characteristic features of lithophysæ. The anhydrous glass was partly converted into a hydrous silicate, accompanied by considerable increase of volume; part was reduced to a white mass distinctly fibrous with a delicate banding parallel to the surface of the glass tube and across the direction of the fibres. The surface of the tube was in places warped, blistered and excoriated, and often full of cracks. There was, also, a delicate foliation parallel to the surface of the tube. Under the microscope the altered glass contained minute spherulites, microlites, and small crystals of pyroxene (diopside), and larger spherulites, probably chalcedony. The surface of the glass was covered with prismatic crystals of quartz. The transformation was wholly produced by the influence of superheated steam.

In the case of the obsidian from Obsidian Cliff, chemical analyses show a loss upon ignition of 0·66 per cent. That this loss is mostly due to water seems probable from the researches of MM. Boussingault and Damour, and others, whose very careful tests have shown the presence of water and a little chlorine in a number of obsidians. That this amount of volatile matter is sufficient to convert the dense obsidian into pumice like that on the surface of this lava flow, is shown by melting a frag-

* Bull. Soc. Min., 1879, ii, p. 158, and 1880, iii, p. 171; also Comptes Rendus, 1881, xciii, p. 1374, and 1883, xcvii, p. 290, 294.

† Amer. Chem., 1883. Also Tschermn. miner. u. petrogr. Mitth. iv, p. 536.

‡ Etudes Synthetiques de Geologie Experimentale, 1879, p. 154 to 179.

ment of the obsidian in the flame of an oxyhydrogen blowpipe, when it becomes a greatly inflated white glass filled with gas bubbles which arise from the expansion of the liberated vapors. This shows that the gases which escaped at the surface with the formation of pumice were imprisoned in the dense obsidian which solidified lower down in the mass. As already stated, the larger spherulites are filled with multitudes of gas cavities recognizable under the microscope.

These vapors were, undoubtedly, absorbed by the molten lava before its eruption, and were the only gases which may have taken part in the production of lithophysæ, for chemical analyses of the obsidian, spherulites and lithophysæ show that they have essentially the same chemical composition. The analyses of spherulites and lithophysæ which occurred isolated in dense, unfractured obsidian are enough alike to be duplicates. The composition of both being the same, the transformation of a spherulite into a lithophysa, can only be a modification of its structure or a rearrangement of its minerals without any chemical addition or loss. Moreover, it is evident that such a transformation was in many cases effected by agencies entirely within the area of the lithophysæ, for they often occur isolated in the dense obsidian having no connection with other cavities or sources of vapor.

The change took place before the surrounding matrix had solidified, for in some instances the lithophysæ have been crushed, probably from a change of equilibrium in the lava, and the plastic matrix has been forced part way into the cavity of the lithophysa, which indicates that the matrix was still viscous and at a high temperature when the modification of the spherulite took place. And finally, though the matrix was plastic at the time of the formation of the cavities of lithophysæ the liberation of gases did not expand or distend the substance so as to form the concentric shells, for where a lamination is present in the matrix it is also seen traversing the shells of a lithophysa without change of direction.

From the foregoing it seems reasonable to infer that these lithophysæ, composed of prismatic quartz, tridymite, soda-orthoclase, fayalite and magnetite, *are of aqueo-igneous origin, and have been produced by the action of the absorbed gases upon the molton glass from which they were liberated during the crystallization consequent upon cooling.*

Instances where the layers of thinly laminated rock arch over hollow lithophysæ and seem to have been pushed back by expanding gases, to which von Richthofen calls attention, are more probably slight flexures in the layers of the rock which have occasioned local relief of pressure and the disengagement of vapors which might give rise to the lithophysa,

than the result of the expansion of such vapors. For the field study of the rock at Obsidian Cliff shows that in places it was so stiff and viscous before coming to its final rest that some layers which were pulled apart in descending the underlying slope never closed together again. Hence it is likely that local inequalities of pressure might be brought about by the crumpling of so viscous a lava.

We may imagine the process of formation of a lithophysa to have been somewhat as follows: In the still plastic glass from a center of crystallization a multitude of incipient microlites of feldspar radiated through a sphere of glass. As these anhydrous microlites increased in size the nature of the cementing paste was changed. Being impoverished of alumina and alkalies, it became more siliceous and relatively more hydrated. A point was reached where the absorbed vapors could no longer be retained in combination, but were released in innumerable bubbles which were either uniformly disseminated through the paste or aggregated into larger bubbles. The gas thus liberated acted as superheated steam and eventually produced the separation and crystallization of all the elements of the original sphere of plastic glass. Before the final crystallization of the paste when the hydrated glass gave up its combined vapors and became anhydrous, it shrank in consequence of the reduction of volume and produced in some cases the cracks so frequently observed. That these cracks were formed before the final crystallization of the cementing paste is shown by the deposition on their walls of crystals of quartz, tridymite and fayalite. The conditions which produce a concentrically banded structure in some solid spherulites are most likely the same as those which lead to the formation of concentric shells in many lithophysæ. It is evident that the development of lithophysæ in a lava will depend upon a number of conditions both chemical and physical, the discussion of which is omitted from this paper.

Laminated structure.—The lithoidal portion of the obsidian flow which forms Obsidian Cliff is beautifully laminated in thin layers of light and dark shades of a purplish gray color, which differ in their relative denseness and degrees of crystallization. The more crystalline layers are full of minute cavities and thus become planes of weakness in the rock, which splits into thin plates, often not more than $\frac{1}{16}$ of an inch thick. So that the lithoidal rock is traversed by a multitude of nearly horizontal cracks which follow the planes of flow through all their contortions. It is this inherent lamination or layer structure, so commonly observed in the more acid lavas and especially the rhyolites of the Yellowstone National Park, which was alluded to in the paper on columnar structure published in

this Journal in May, 1886 (page 325.) It was there considered to be of different origin from the tabular parting produced by rapid cooling near the surface of a body of molten rock.

The origin of the more general lamination which in one form or another usually extends throughout the whole mass of many lava flows will be readily understood from the following:

In a fluid free to flow over a horizontal surface the movement of its molecules will meet with least resistance in directions parallel to the plane of that surface, the fluid will therefore spread horizontally, and its molecules will move in planes parallel to the underlying surface. Particles suspended in the fluid will be carried along these planes, and portions of the fluid which contain different amounts or different kinds of suspended matter will be spread out in layers along these planes of flow.

In volcanic lavas the production of such layers will depend on the lack of homogeneity and viscosity of the magma, and the distance over which the lava flows. The more basic lavas are usually more liquid and consequently more homogeneous at the time of eruption, and show little if any signs of layer-structure in the solidified rock. But acid lavas such as rhyolite appear to be more viscous and less homogeneous when erupted, and slight variations in the consistency or composition of the mass show themselves as bands and streaks of colors or as layers of differing microstructure and degree of crystallization. These layers of different consistency were probably lenticular or quite irregularly shaped portions of the magma near the place of its eruption, and are more perfectly and thinly laminated the farther from the source.

The nature and cause of such local differences in the magma is suggested by a consideration of the structure of the various layers of the rock forming Obsidian Cliff. The lithoidal rock presents layers which differ in their degree of crystallization, some being wholly uncrystallized and glassy. Some are finely spherulitic, others coarsely so and porous; and others are quite granular and full of cavities. In the obsidian the differences find expression in layers of spherulites, and bands of lithophysæ; in layers more or less rich in granophyre feldspars, microspherulites, microlites and trichites; that is, in the different phases and amount of crystallization developed. Nearer the surface of the obsidian flow there is less crystallization, but the lamination of the rock is quite as noticeable in the more marked differences in the amount of microlites in the various layers and in the abundance of gas cavities which produce alternating bands of vesicular and dense glass and pumice. While at the surface of the flow the whole rock is openly pumiceous.

From the different extent to which the various layers of this glassy rock have been inflated by the expansion of gas near the surface of the flow it is evident that there was a difference in the amount of vapors previously absorbed by these layers. And from the part which superheated water has undoubtedly played in the development of lithophysæ and the larger, porous spherulites, and from the aqueo-igneous conditions deemed necessary for the production of the granophyre groups of quartz and feldspar, it seems highly probable that *the differences in consistency and in the phases of crystallization producing the lamination of this rock were directly due to the amount of vapors absorbed in the various layers of the lava and to their mineralizing influence.*

ART. V.—*The latest Volcanic Eruption in Northern California and its peculiar Lava;* by J. S. DILLER.

IN making a geological survey of the northern terminus of the Sierra Nevada range in California, under the direction of Captain C. E. Dutton, to determine its relations to the volcanic phenomena farther northward, several opportunities were afforded to visit and study the phenomena resulting from the latest volcanic outburst in that region. It occurred at a place which is now pretty well known in that part of the world as "The Cinder Cone" near Snag Lake, about ten miles northeast of Lassen Peak, in Northern California. The newness of all the phenomena connected with this volcanic eruption is so striking when compared with those of other outbursts in the same vicinity that many of the country people and tourists are led annually to visit the locality, but until recently it has not been carefully investigated.

The Cinder Cone is a remarkably regular truncated cone rising about six hundred and twenty feet above the lowest portion of its base, and is composed almost exclusively of small scoria and lapilli. Its slopes are from 30° to 35°, just as steep as it is possible for such material to lie. The original form of the crater, which is marked by a pit over two hundred feet deep in the summit of the cone, is perfectly preserved. Upon its barren slopes the only vegetation seen is one small bush, but within the crater rim hidden from general view, there are a few pines whose trunks are several inches in diameter.

The lava field resembles an immense tabular stone pile covering an area of about three square miles, and ending upon all sides with steep slopes like a terrace over a hundred feet in height. Its surface, although champaign, is extremely rough,

being formed by a mass of broken angular blocks of lava, and completely impassable to beasts of burden. The fragmental stony character of the lava flow resulted from its extreme viscosity at the time of the eruption. The crust was repeatedly broken up by the friction and pressure of the moving viscous lava beneath, and shoved along in such a way as to round some of the fragments by attrition.

About the lava field, and extending away from it in all directions, for a distance of from ten to twelve miles is the field of volcanic ashes. It is covered with pine forest which has attained the maximum development for that region. Close to the base of the Cinder Cone the thickness of the ashes could not be readily ascertained. One-fourth of a mile away, however, they are over seven feet in depth and gradually thin out to the border of the field. In the immediate neighborhood of the cone a trunk of *Pinus ponderosa* growing directly upon the upper surface of the sand has a circumference of over twelve feet. There are numerous dead trunks of the same pine standing near by which were evidently killed at the time of the eruption. Excavations at the bases of these trees show that they extend down through the volcanic sand to the original soil over seven feet beneath the present surface. Many of the trees killed at the time of the eruption have decayed and disappeared, but their positions are marked by numerous pits upon the surface where the sand has slid in to take the place of the decayed wood.

It is obvious that the volcanic sand of the ash field is continuous with the material of the Cinder Cone, and that both are products of the same eruption, and older than the lava with which they are associated. The lava plainly belongs to two periods of effusion separated by a time-interval during which over six feet of infusorial earth was deposited upon the older portion. At the time of the final eruption, when the ancient lake bed was in many places raised above the present level of Lake Bidwell and Snag Lake was formed, the great mass of the lava was quietly extravasated without any ejections whatever from the Cinder Cone.

The lava is readily recognized as basalt, one of the commonest of all types of late volcanic rocks. It has all the essential constituents of ordinary basalt, i. e. plagioclase feldspar, augite and olivine together with accessory magnetite and a large proportion of unindividualized material which is generally globulitic. In addition to all these characteristic constituents of basaltic lava this basalt is remarkably anomalous in containing numerous grains of quartz.

Only four probable hypotheses suggest themselves in explanation of the origin of these quartz grains in the basalt. They

may be regarded: (1) as remnants of the rock from which the basalt may have been derived deep in the earth by fusion; (2) as inclusions picked up by the lava on its way to the surface at the time of the eruption; (3) as crystallizations from the magma itself; (4) as of secondary origin derived by the alteration of other minerals.

The absolutely fresh unaltered condition of the basalt forbids the belief that the quartz is of secondary origin and the character of the quartz is such as to render equally untenable the view which regards it as a remnant of the original rock from which the basalt may have been derived by fusion. So we have left to determine whether the quartz grains are inclusions or secretions.

The fractures in the quartz grains and the border of glass and pyroxene by which they are surrounded have been considered characteristic of quartz inclusions, but in fact such phenomena are equally common to some other minerals which are universally regarded as early secretions in the magma. The quartz always occurs without well defined crystallographic form in clear, vitreous, roundly-corroded grains just as in some of the more acid porphyritic rocks where all observers agree that it is indigenous to the lava. If the quartz grains are regarded as inclusions and we consider their multitude we would expect to find a greater range in their size and in the kind of included material. Fragments of any other sort in the basalt have been diligently sought for in vain. These considerations lend much support to the view which conceives the quartz to be an early secretion in the magma, but a more impressive argument in its favor is based upon the uniform distribution of the quartz grains throughout the entire mass of the lava including all its fragmental forms. It is as intimately intermingled with the other constituents of the basalt as the feldspar and the olivine, only somewhat less abundantly. To fully appreciate this fact the basalt must be examined in the field where it appears impossible to explain the omnipresence of the quartz satisfactorily on any other supposition than that it originated in the magma itself. We must bear in mind also that this particular basalt was very viscous and stiff at the time of its eruption, so that it broke up and shoved along over the surface as a great pile of stones. On account of the high degree of viscosity, inclusions would be found only in the basalt which came up very close to the side of the volcanic chimney and they would not spread into other parts of the lava. Of this I was fully convinced by an examination of the volcanic necks near Mt. Taylor in New Mexico. They are of basalt, which at the time of its eruption was apparently more liquid than that containing the quartz at the Cinder Cone near Snag

Lake. Before reaching the surface the basalt of the necks traversed several thousand feet of horizontal shales and sandstones which in some places are so friable as to easily crumble in the hand. A more favorable opportunity than this cannot be imagined for the basalt at the time of its extrusion to become thoroughly impregnated with grains of sand. Nevertheless no trace of quartz grains or small fragments of sandstone is found a short distance inside of the boundary of the neck.

The abundance of the quartz grains in the large volcanic bombs is a fact of special significance. It is evident that at the time of the eruption the bombs were thrown up into the air and falling upon the steep slopes of the Cinder Cone they tumbled to its base, where they collected in great numbers. The bombs vary in size from half a dozen inches to over eight feet in diameter. They are nearly round, and toward the center are very compact and jointed frequently in such a manner that the fissures radiate from the center of the bomb. The surface is rough, often vesicular and pumiceous. If the bombs had been soft at the time of their ejection as is frequently the case, they would have flattened out when they struck the ground, but from the fact that they remained round it may be inferred that they were already solid at the time of the eruption, having previously floated around as clots in the magma. These bombs are undoubtedly the oldest portion of the lava, having solidified previous to the eruption or in its earliest stage, before the magma in which they were suspended reached the surface. The fact that the grains and lumps of quartz are abundant to the very center of the largest bombs demonstrates that they are early secretions from the magma at a time when it was under enormous pressure. During the eruption the pressure was relieved and the consequent conditions of solubility changed, so that the quartz secretions, like those of the more acid lavas, were partially redissolved or fused, giving rise to the zone of glass and pyroxene by which the quartz is surrounded.

The quartz basalt is younger than any of the many basalts about it. There are numerous cinder cones and recent flows of basalt upon all sides of the one under consideration, and yet, although they were extravasated through the same formations and under the same conditions as the quartz basalt, they contain no quartz. This fact indicates clearly that the source of the quartz is to be found in that of the basalt itself.

Until recently I had supposed that there was only one locality of quartz basalt in that region, but later investigations in the field have discovered another near Silver Lake, twenty-five miles northwest of Lassen Peak, about an entirely distinct volcanic center. It has all the peculiar features of the quartz

basalt at the Cinder Cone and like it is the youngest lava of that vicinity.

Grains of quartz have been noticed by other observers in basalts from various parts of the world, but they have been almost invariably considered to be inclusions of entirely foreign quartz picked up at the time of the eruption.

The great difficulty which has stood in the way of considering the quartz as indigenous to the basalt is of a chemical nature, and on account of it, petrographers generally are disinclined to admit that it is possible for quartz to crystallize in a magma which yields olivine. It must be borne in mind, however, that the quartz and the olivine did not crystallize synchronously nor under the same conditions. The quartz is older than the olivine and crystallized under great pressure far beneath the surface in that region where the conditions of physical and chemic equilibrium are as yet so largely conjectural. The crystallization of the olivine was rendered possible by the earlier secretion of free silica.

Chemical Analysis of quartz basalt from the Cinder Cone.

SiO_2	57·25
TiO_2	0·60
Al_2O_3	16·45
Fe_2O_3	1·67
FeO	4·72
MnO	0·10
CaO	7·65
SrO	*trace*
BaO	0·00
MgO	6·74
K_2O	1·57
Na_2O	3·00
Li_2O	0·00
H_2O	0·40
P_2O_5	0·20
	100·35

The accompanying chemical analysis of the quartz basalt from the Cinder Cone near Snag Lake has been made for me in the labo atory of the U. S. Geological Survey by W. F. Hillebrand. The high percentages of silica and magnesia are to be noticed in connection with the low percentages of the oxides of iron.

Corroded quartz is abundant in the quartz porphyries and rhyolites, less abundant in the andesites and rare in the basalts, nevertheless its presence is an essential feature of the basalt in which it occurs and may be used as one of the means of dis-

tinguishing certain lavas as quartz-basalts, just as it is used in other cases to characterize quartz andesite. The separation of the basalts into ordinary basalts and quartz basalts is not a purely mineralogical classification but is founded upon their chemical composition as well as upon their genetic relations expressed in their *natural order* of eruption—the quartz basalts in every case known being younger than the other basalts of the same region just as the quartz andesites (dacites) are younger than the other andesites of the same volcanic center.

Petrol. Lab. U. S. Geol. Survey, Washington, D. C., Nov. 19, 1886.

ART. VI.—*The Texture of Massive Rocks;* by GEORGE F. BECKER.

AN opinion has been gaining ground among geologists for some years past, that the principal differences in the texture of massive rocks are due to differences in the rate of cooling and differences in the pressure under which the masses have consolidated. That slow cooling will convert into a partially crystalline mass a magma which, if rapidly chilled, would remain substantially in the form of glass is known experimentally* and observations on volcanic flows are accordant with experiment; for it is certain that glass is often abundant at the surface of lava streams and that it is chiefly confined to moderate distances from the original surfaces of eruptive masses, although minute particles of glass may frequently be found at considerable depths. It may readily be granted, that at a sufficient depth all trace of glass would disappear; or that an ordinary, homogeneous, eruptive magma may be cooled so slowly and under such pressures as to yield a holocrystalline product. Whether or not the pressure is influential in this respect is questionable.

It is supposed to be a mere extension of this thesis to maintain that the difference between porphyritic structure and granular structure is due to a similar difference in the physical conditions to which the fluid magma has been subjected. The inference has thus been drawn, that if the material constituting a given holocrystalline porphyry had been cooled sufficiently slowly and under sufficient pressure, it would have assumed the granular structure of typical granite or diorite.

This appears to me to be a wholly different and almost an unrelated proposition rather than a legitimate extension of the preceding. The immediate origin of granular structure is the

* The best example is perhaps "basaltified" iron blast-furnace slag, which has been used to a large extent for street pavements.

simultaneous development of different crystalline grains, each of which, as it increases in size, interferes with the growth of others. A porphyry, on the other hand, is produced when only one or two minerals, crystallize from a homogeneous fluid in advance of the remainder and individual crystals of these favored species are afforded an opportunity to reach a comparatively large size and a good crystallographic development. Porphyritic structure is thus certainly due to what chemists would call "fractional" crystallization. Granting that a given homogeneous fluid may be cooled so slowly and under such pressures as to yield a holocrystalline porphyritic product, it certainly does not follow as a matter of logic, that if it were cooled still more slowly and under a still greater pressure, the various ultimate compounds would crystallize simultaneously. Neither does this conclusion follow as a matter of chemical or physical theory. The solidification of minerals must proceed, as I have shown in a former paper,* in obedience to the principle that the particular compound, the formation of which in the solid state liberates heat at the highest rate, will be the first to separate. Now it is certain that, in general, the formation of different solid compounds is attended by the liberation of heat at different rates; and the more slowly the conditions change the more perfect will be the divisions between the intervals of time during which different compounds will be precipitated. If a chemist desires to separate salts by partial crystallization, he will cool or evaporate his solutions as slowly as possible. It would thus appear both from experiment and from theory that if a homogeneous eruptive magma were cooled very slowly indeed, one or two minerals would be most likely to crystallize at first, or early in the process, and to attain good crystallographic development; that if these minerals constitute a fairly large portion of the mass, they would eventually build up a framework full of interstices; that as the solidification proceeded beyond this point and other compounds crystallized out, these could no longer develop symmetrically but must be crippled by the interference of earlier crystals and by mutual opposition. In short one would expect to obtain a holocrystalline porphyry as the product of a homogeneous fluid glass slowly cooled.

Geological observations bearing upon this subject are readily accessible. Every microscopical lithologist knows that some minerals show the clearest evidence of early separation from eruptive magmas, being imbedded in other crystals; and that such minerals, for example apatites, are very usually well-developed crystals; indeed irregular crystalline grains of apatites are very rare in lavas. Eruptive magmas do then separate out

* A new Law of Thermochemistry, this Journal, 1886, vol. xxxi, p. 120.

some minerals before others ("crystals of primary consolidation," as they are called by Messrs. Fouqué and Michel Lévy), and the earliest of these crystals have good crystallographic development. Eruptive magmas thus obey a similar law to that observed experimentally in artificial fluids. It is usually accepted that many of the crystals of primary consolidations are formed prior to the eruption of lavas; indeed I cannot remember to have seen this denied, and yet it may be advisable to dwell somewhat upon the evidence of the fact.

Darwin,* Mr. Clarence King † and others before them have observed that when small branches are thrown out from lava streams of active volcanos and rapidly chilled, crystals of feldspar and augite are found accumulated at the lower surface, while the upper portions consist of nearly pure isotropic glass. It is substantially certain that these crystals cannot have formed during the short interval elapsing between the rise of the material to the surface and the moment of complete consolidation. Hence the crystals must have been suspended in the lava as it came to the surface and must have formed at a distance from the surface which is to be measured by miles. There is also other evidence nearly or quite as strong. Near the Comstock I found (in a slide) a crystal of hornblende, bounded on all sides but one by sharp crystallographic outlines. The remaining side appeared to represent a fractured or rather split surface, about one-half of the cross section of the prism being gone.‡ This fractured crystal is solidly imbedded in the groundmass of the rock, and the fracture must consequently have taken place while the groundmass was still fluid. It is almost or quite impossible to suppose any conditions under which this crystal can have been broken excepting those attending the actual rush of the lava from a profound depth to the surface. Hence it is as nearly certain as possible that this hornblende must have formed before eruption and under the pressure of miles of rock.§ The fact that "flow structure" is common immediately about porphyritic crystals in eruptive rocks, is by itself almost sufficient to show that the formation of these crystals antedates eruption. The larger the crystals of primary consolidation the less probable it is that they were formed after the eruption of a porphyry. In the Washoe district there is an area of hornblende andesite in which the rock is studded with unusually large and very finely developed hornblendes.‖ An immense number of these are an inch and

* Volcanic Islands, chap. VI. † Systematic Geology, p. 716.

‡ Geology of the Comstock Lode, p. 59 and Plate III. The double black border shows clearly that the crystal must have been split.

§ Others have also observed fractured or bent crystals in lavas.

‖ Geology of the Comstock Lode, p. 57.

a half in length and proportionately thick, while I found one specimen four inches in length and about three-quarters of an inch in thickness. It seems unnecessary to insist that crystals of such a size cannot have formed after ejection. The groundmass of this andesite did not differ essentially from that of an ordinary hornblende andesite.

Suppose that this rock had remained in its original position at least five miles below the surface and under the pressure of some 30,000 pounds per square inch until, by gradual refrigeration, the entire mass had become solid. There would probably have been no residual glass, or the mass would have become holocrystalline. But, as the interstices between the hornblendes gradually filled with other minerals, and after a certain portion of the entire mass had become solid, the growing crystals must have been crippled by mutual interference and the opposition of the already completed crystals. In short it is not possible that a more or less granular groundmass should have been entirely absent and, even if this rock had cooled at an imperceptible rate and under a stupendous pressure, it would still have yielded a porphyry and not a rock of granitoid structure.

Evidence of this kind could be indefinitely adduced and it is in the hands of every geologist. It appears to me to lead inevitably to the conclusion that porphyries may be formed from homogeneous fluid magmas at pressure however great, and at temperatures which sink at never so small a rate. If so, the formation of rocks of the structural type of granite from homogeneous fluid magmas must represent only extreme and highly exceptional cases of a curious neutral chemical equilibrium.

Conditions the very opposite of those attending the consolidation of fluid eruptive magmas are present in sedimentary rocks undergoing crystallization as a feature of metamorphism. The chemical composition of a sedimentary rock usually varies from millimeter to millimeter. If it is permeated by a chemically active fluid, the reaction which will liberate heat most rapidly varies with the locality as rapidly as the composition. Hence innumerable centers of a whole range of reactions are simultaneously established, a number of minerals equal to that of the reactions begins to crystallize at once, and no one mineral has, as a rule, an opportunity to exhaust the materials of which it is built up before it is interfered with by others. Thus among metamorphic crystalline rocks a granular structure should be the rule and a porphyritic structure should represent rare exceptions. This is of course true. The commonest partial exception is in the case of garnet and is due to the power which garnet possesses to an unusual degree of including solid foreign material. There are cases however which I have carefully studied, in which a metamorphic mass for a few cubic

inches possesses as good a porphyritic structure as a true eruptive rock, just as granular patches may sometimes be found in typical porphyries.

It would appear then that a porphyritic structure should be the rule among rocks which have attained a high degree of fluidity, while a granular structure should be characteristic of metamorphic rocks. So far as geologists are fully agreed, this is true, for opinions are divided as to the origin of granite and allied rocks.

Many geologists, and I am among the number, do not question that there are both eruptive and metamorphic granites, diorites and diabases. If this is granted, or assumed to be true for the sake of argument, either the intrusive, granular rocks of typical habitus have been as fluid as lavas, and therefore represent the extreme case in which various reactions liberate heat at exactly the same rate; or else, like the metamorphic rocks, sometimes quite indistinguishable from them, they have never been sufficiently fluid to reach substantial homogeneity. Of these two suppositions the former seems very improbable, because granular rocks are not exceptionally rare and must have been formed under widely prevailing conditions. The alternative supposition, that granular rocks as a whole have never been thoroughly fluid, does not represent a strange chemical equilibrium and is not *à priori* improbable.

The rapid variation in texture and mineral composition of many granites is familiar to all geologists and they can draw their own conclusions from the evidence which this rock presents as to the former fluidity of the granitic magma. Scheerer and others long ago maintained that granite had never been raised to a high temperature or been reduced to a condition of perfect fluidity. I prefer to employ as an illustration the diorite of Mt. Davidson, which forms the foot wall of the Comstock lode in the mines known as the central group, between Spanish ravine and Bullion ravine. It forms a bare, unbroken exposure from the top of the mountain to the croppings of the lode, a vertical distance of 1300 feet and has been open to my observation at several points in the mines down to a depth of 3,000 feet below the croppings. The horizontal distance between the two ravines is about three-fourths of a mile. Geologists have perhaps seldom had an opportunity of examining a single rock-mass of this kind over a vertical distance of 4,300 feet within a horizontal distance of just about one mile. The exposures in the mines are no longer accessible and will probably never again be opened up.

From top to bottom this mass presents the same general character. The earlier visitors to the region called this rock granite, but as it contains little or no quartz, Baron von Richt-

hofen designated it as syenite. It continued to be thus classed until Professor Zirkel showed by microscopic examination that it is a plagioclase rock. These facts are cited to show that it is substantially a granular rock of the granitic type. So nearly as I can estimate, about 95 per cent of the mass is granular, the remainder consisting of more or less porphyritic matter. While the general character of the rock is everywhere the same, there are considerable and rapid changes in the composition and the texture of the material from point to point; but the same varieties occur over and over again within short distances and are everywhere confined to substantially the same range. Thus during the summer of 1885 I studied with care the excellent and extensive exposures which had just been made on the 3000-foot level of the Chollar mine. Here I collected every variety of the rock exposed, and of these six or eight were distinguishable either by coarseness of grain, or by a more or less pronounced porphyritic texture. I carried these specimens to the west wall of the croppings, 3,000 feet above the same claim, or in the same vertical plane, and found neither any general difference nor any difficulty in matching each specimen from below by others from the surface. For the interval between the croppings and the summit of the mountain similar statements hold true. There is throughout, no indication of a tendency to a change varying with depth below the summit.

The bare, faulted slopes of Mt. Davidson afford an admirable opportunity for a study of the relations which exist between the porphyritic and granular forms of diorite. Patches of porphyritic rock are surrounded by granular material, and patches of granular matter are surrounded by a porphyritic rock. Neither one nor the other form inclusions. They resemble the dark spots so constantly met with in granite and, in innumerable instances, show a transition from one structure to the other. In some cases this transition is rapid though unmistakable, in others it is so gradual that it would be impossible to decide within some inches where to draw the line between the granular and porphyritic forms. Only a very small portion of this mass is micaceous. Here may be found a single flake of biotite, there a group of flakes fading out from a centre into the ordinary granitoid mass.

It is manifest that where a spot which is a few inches in diameter fades out into the surrounding granular mass, the material of which each is composed must have been subjected to identical physical conditions. Neither can have chilled more rapidly than the other and the pressure on each must have been the same. But the differences between rocks can be due only to physical or chemical conditions. The porphyritic portions of this rock must therefore have a different composition from the

granular portions, and the constitution of the micaceous portions must be different from that of either of the others. In short, original differences in composition are necessary and sufficient to explain the differences in texture; and since the composition varied enough to produce striking differences in texture, the magma can never have been homogeneous and therefore it can also never have been thoroughly fluid. It also seems quite clear, from the results reached in preceding paragraphs, that those portions which were more fusible and became fluid, solidified as porphyry, while those portions which were only reduced to a pasty condition and which consisted of rather intimate mixtures of somewhat heterogeneous material, solidified as a granular rock. The melting point of most bodies rises with the pressure.* It is therefore in so far conceivable that a column of homogeneous eruptive rock of uniform temperature should exist, the upper portion of which is fluid and the lower portion pasty. Such a column might solidify to a porphyry near the upper end and to a granitic mass at the lower end. The lack of knowledge of the relation between melting points and pressures of minerals makes it impossible to assert that such cases may not sometimes occur in nature, but, if so, they must be exceptional. Positive evidence has been given above that porphyries such as andesites must be fluid enough to allow of free crystallization before eruption and at pressures which I believe must greatly exceed those at which any rocks accessible to dwellers on the surface of the earth can have solidified. A column of andesite of which the lower portion was rendered pasty by mere pressure would have to exceed in length the distance from its point of eruption to the source of the lava, probably not less than five miles and very likely much more. Again if the lower end of a column, say 10,000 feet in length, were rendered pasty by mere pressure, it would

* Lavas not seldom contain crystals of primary consolidation which appear to be rounded, as if they had been partially fused after crystallization. The formation of black borders on hornblende may also indicate a partial fusion or softening of these crystals. These phenomena are almost certainly attendant upon eruption, and if they indicate real fusion, lead to the conclusion that the melting point of such minerals actually falls with diminishing pressure. Bodies, the melting point of which varies in the same sense as the pressure, are denser in the solid than in the fluid state at the melting point, and this question consequently has a bearing on the problem of the solidity of the earth. In the Hawaiian lavas the glass ejected has substantially the composition of basalt and the fact that, as Mr. King observed, the chief constituent minerals sink in and are heavier than this glass, points in the same direction; though unless there are really indications of fusion of the crystals it remains uncertain how far from this melting point the separation by density took place. Other purely geological phenomena also tend to the same conclusion. Thus Captain Dutton has observed that the crusts which form on the melted lavas in the craters of Hawaiian volcanoes often break up and sink. These crusts are of course largely glass, but glass is certainly as a rule less dense than the minerals which crystallize from it, so that were the crusts holocrystalline they would sink only the more readily.

become still less fluid if it were subjected to several times this pressure. Such material at a distance below the surface of five or more miles, would lose so much of its plasticity that it may be doubted whether it could furnish the material for an ordinary volcanic eruption. Finally, if the influence of pressure on the fusibility were such as to make a notable difference in the fluidity of a column of lava 10,000 feet in height, the melting point of crystals which had separated out five miles below the surface would be so much reduced by the relief of pressure attendant upon eruption that they would completely fuse. The preceding paragraphs show that this is not the case with those minerals which form the larger individuals in porphyries. But hornblende, pyroxene, mica, plagioclase and orthoclase all play this part in the porphyries, and they are also the chief mineral constituents of the granular rocks. The supposition that a column of lava 10,000 feet high of uniform and representative composition, which is fluid near the top, can become pasty near the base through mere pressure thus conflicts with well-ascertained facts. It is easy to see that if the opposite law of fusibility prevailed, or if the melting point rose as the pressure diminished, there could be no tendency to the disappearance of porphyries with increasing depth.

On the other hand the diorite of Mt. Davidson and many granites are known to overlie sedimentary rocks later than the Archæan and must, therefore, have solidified within a moderate distance from the surface; so that while no amount of pressure is known to be sufficient to prevent the formation of porphyry, granular rocks may form at very moderate pressures.

The foregoing considerations seem to me to justify the following conclusions:

The relation between holocrystalline porphyries and granular rocks is of very different character from that which exists between glassy rocks and those which are completely devitrified. Porphyries may form at any depth and no matter how slowly the temperature of the magma may sink. Granular rocks, except in a just conceivable limiting case which must be exceedingly rare, can never have been thoroughly fluid or homogeneous, but have often consolidated at pressures extremely moderate compared with those at which it is certain that porphyries would form. When granular and porphyritic forms of a rock are associated, as at Mt. Davidson, the cause of difference in texture is usually a variation in chemical composition, and the temperature to which the rock has been subjected must have been sufficient to melt portions of the mass but not the whole. The indications are that granular rocks have been formed at a lower temperature than porphyries of exactly the

same chemical composition, and that the granular rocks as a group have been less intensely heated than the porphyries.

It is well known to those who are likely to read the foregoing pages, that Messrs. Hague and Iddings have drawn very different conclusions* from a study of my collections from the neighborhood of the Comstock lode; and that they have disputed many of the results both lithological and structural reached in my memoir on that great ore-deposit.† I have replied to their conclusions elsewhere;‡ but I may be permitted to repeat here, that I have re-examined the district and mines with their paper in hand and am only the more convinced that my elucidation was substantially correct. The diorite, diabase and augite andesite are not a single eruption or series of eruptions, as they maintian; but constitute three and probably four eruptions which took place at long intervals of time. There is very strong evidence that the diorite and diabase are pre-Tertiary rocks both at the Comstock and that Steamboat Springs, six miles distant, where diabase pebbles are included in metamorphic conglomerates of pre-Tertiary (probably Jura-Trias) periods. The earlier hornblende andesite of my report is intermediate in age between the diabase and the augite andesite. The quartz porphyry is pre-andesitic, orthoclastic and does not intersect the Sutro tunnel. The Washoe district presents no valid argument for asserting a progressive increase of crystallization in the rocks, while it offers the strongest arguments in favor of the conclusions drawn in this paper.

U. S. Geological Survey, Washington, D. C., Oct. 1886.

ART. VII.—*A fifth mass of Meteoric Iron from Augusta Co., Va.;* by GEORGE F. KUNZ.

THIS mass of meteoric iron was given to the late Colonel W. B. Baldwin, of Staunton, Augusta Co., Va., and was found at or near the place where the largest of the three masses from Augusta Co., first described by Professor Mallet,§ was found. Col. Baldwin was under the impression that it was a detached part of the largest mass. Professor Mallet received it from him at a considerably later date than the large mass, and having chipped and filed a small flat surface, he found, after etching, that the Widmanstätten figures were like those on the large mass. A careful examination satisfied him that this piece of iron had not been in any way artificially detached from any one

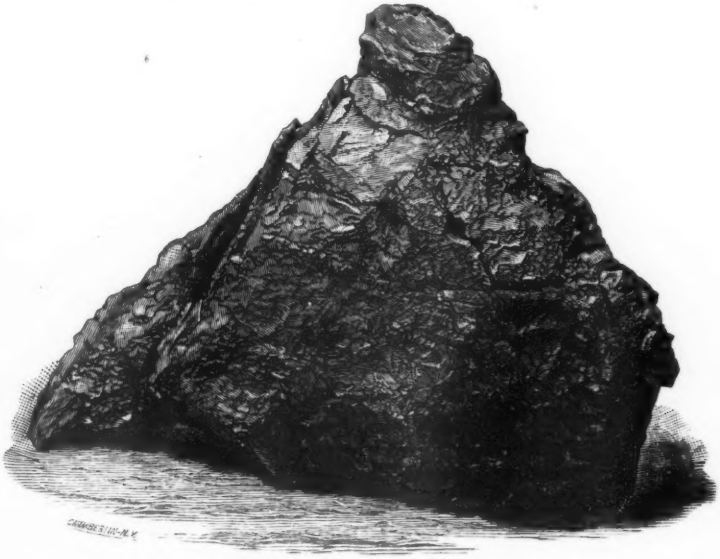
* Bull. U. S. Geol. Sur., No. 17.

† Geology of the Comstock Lode, etc., U. S. Geological Survey, Monograph III.

‡ Bulletin of the California Academy of Sciences, No. 6, p. 93.

§ This Journal, III, ii, 10, 1871.

of the previously discovered masses, though there is no doubt that all the other four meteoric irons from Augusta Co., including the one now described, are portions of a meteorite which probably exploded in mid air. Its present dimensions are 8·5^{cm} by 6·5^{cm}, 7^{cm} at the widest end and 3^{cm} at the smaller end. This, like the other masses, contains ferrous chloride which, by its deliquescence, has caused much of the mass to exfoliate and crack off, so that this mass is only a nodular remnant of what was formerly a much larger mass. At one end (see figure) there is a large fragment weighing several hundred grams, that is in part separated by a fissure 4^{mm} wide—a result of oxida-



tion. Several fracture pieces show from four to six faces of the octahedron. The following analysis of the mass is kindly furnished by Professor J. W. Mallet:

Iron	90·293	Phosphorus	·243
Nickel	8·848	Sulphur	·012
Cobalt	·486	Chlorine	trace
Copper	·016	Carbon	·177
Tin	·005	Silica	·092
Manganese	trace		
Chromium	trace		1000·72

ART. VIII.—*Note on the origin of Comets;* by DANIEL KIRKWOOD.

HAVE comets originated in the solar system, or do they enter it from without? This question has been considered by Laplace, Proctor, H. A. Newton, and others. The last named presents arguments of no little weight in favor of their origin in inter-stellar space.* To these arguments I shall attempt no reply. On the contrary, I have been disposed to accept them as, in the main, valid. For certain comets of short period, however, various facts seem to indicate an origin within the system.

(1.) According to M. Lehmann-Filhès the eccentricity of the third comet of 1884, before its last close approach to Jupiter, was only 0·2787.† This is exceeded by that of twelve known minor planets. Its period before this great perturbation was about 3619 days, and its mean distance 4·611. It was then an asteroid, too remote to be seen, even in perihelion. Its period was very nearly commensurable with that of Jupiter; six of the one being very nearly equal to five of the other. According to Hind and Krueger the great transformation of its orbit by Jupiter's influence occurred in May, 1875. Its present period is about 6½ years. It was discovered by M. Wolf at Heidelberg, September 17, 1884. Its history indicates an origin in the zone of asteroids.

(2.) *The second comet of* 1867.—This body was discovered by M. Tempel on the third of April. Its perihelion distance is 2·073; its aphelion 4·8973; so that its entire path, like those of the asteroids, is included between the orbits of Mars and Jupiter. The eccentricity of this comet at its successive returns has been as follows:

Date of Return.	Eccentricity.
1867	0·5092
1873	0·4625
1879	0·4624
1885	0·4051

The last is nearly identical with the eccentricity of Æthra, the 132d asteroid, (0·38.) The period, inclination, and longitude of the ascending node are approximately the same with those of Sylvia, the 87th minor planet.

This comet may be regarded as an asteroid whose elements have been considerably modified by perturbation.

Other comets furnish suggestive facts which bear upon the same question; but their discussion must await the development of additional data.

* This Journ., Sept. 1878. † Annuaire, 1886.

Art. IX.—*The Bichromate of Soda Cell;* by Selwyn Lewis Harding.

In view of the recent claims of superiority of bichromate of soda as a depolarizing agent over its companion salt, bichromate of potash, I have made a series of comparative tests of the two salts, the results of which are contained in the following paper:

The points to be examined were the relative constancy or powers of endurance, the electromotive force, and the resistance of the two batteries.

The cells, in every case, were set up in the manner known as the Bunsen battery, namely, dilute sulphuric acid and zinc outside, bichromate solution and carbon inside, the porous cup. The proportions used were those given by the chemical reactions which take place within the cells; these are:

$$Na_2Cr_2O_7 + 4H_2SO_4 + 6H = Na_2Cr_2(SO_4)_4 + 7H_2O \qquad (A)$$

and similarly

$$K_2Cr_2O_7 + 4H_2SO_4 + 6H = K_2Cr_2(SO_4)_4 + 7H_2O, \qquad (B)$$

giving, from (A)

27 parts of $Na_2Cr_2O_7$
40 parts of H_2SO_4

and from (B)

3 parts of $K_2Cr_2O_7$
4 parts of H_2SO

For every part of the bichromate of soda, seven parts of water were used, and for every part of the bichromate of potash eight parts of water.*

The liquid surrounding the zinc was a mixture of twelve parts of water to one of sulphuric acid.

Constancy.—To answer the question of the relative merits of the two bichromates in regard to their constancy or powers of depolarizing, I obtained a series of photographic records of cells set up with these salts. The method of obtaining these records was, in brief, the substitution of a sheet of sensitive paper—driven by clock-work and properly protected from extraneous light—for the ground-glass scale of the ordinary reflecting galvanometer; the place of the zero point on such a scale being taken by a base line traced out by the reflection from a fixed mirror.†

The records thus obtained give a history of the current strength, showing its fluctuations and gradual weakening, from

* The result of later work indicates that a much less quantity of water would be preferable with the soda salt.

† For details, this Journal, vol. xxix, p. 374, May, 1885.

the moment of making until breaking circuit. By transferring the individual records taken under the same conditions to a sheet of coördinate paper and referring them to the same axes, their relative changes from time to time are readily noted. The accompanying diagrams show a number of these records. Fig. 1 illustrates better than many words the relative value of the two bichromate cells, at least as far as their constancy is concerned; it gives two records of each of the two classes of cells, and, for the sake of comparison, a record of a Daniell's cell. It is to be observed that in Series 1 and 2 circuit was made immediately after setting up the cells, before the liquid had time to diffuse itself through the pores of the inner cup. The increased resistance, due to this cause, and the gradual return to the normal resistance during the first hour are plainly recorded. The following table gives the length of the records or the total number of hours before the exhaustion of the depolarizer:

Double Liquid Cells.

	Depolarizer.	External resist.	Hours before exhaustion.
Series 1	Bichr. of potash	8 ohms	$55\frac{1}{2}$
Series 2	" " "	8 "	$56\frac{1}{3}$
Series 3	Bichr. of soda	8 "	78
Series 4	" " "	8 "	$74\frac{2}{3}$
Series 5	Sulphate of copper	8 "	

During the first 24 to 30 hours the records show little difference in the working of the two classes of cells, both remaining comparatively constant and, therefore, giving for records nearly straight lines; though it must be understood that even in the case of the most constant cells, such, for instance, as the Daniell's cell, the curves are never absolutely straight lines but rather a series of slight but numerous fluctuations about the position of a right line. These fluctuations are far more marked during the first 10 or 15 hours than later, but at no time are they entirely absent. Both the potash and the soda cells, in the above series, showed signs of weakening after 30 hours. This weakening, however, proceeded far more rapidly, and, consequently, exhaustion was reached much sooner in the former class of cells than in the latter. As can be seen from the table, the soda cells ran on an average fully 20 hours, or more than one-third, longer than the potash cells.

The comparatively short life of the depolarizing liquids in all the above cases was due to the small resistance in circuit. As a proof that the soda cell is capable of long continued action on a larger circuit, I need only cite a record which lasted, with 35 ohms in the external circuit, over 200 hours without showing signs of exhaustion. On large circuits where

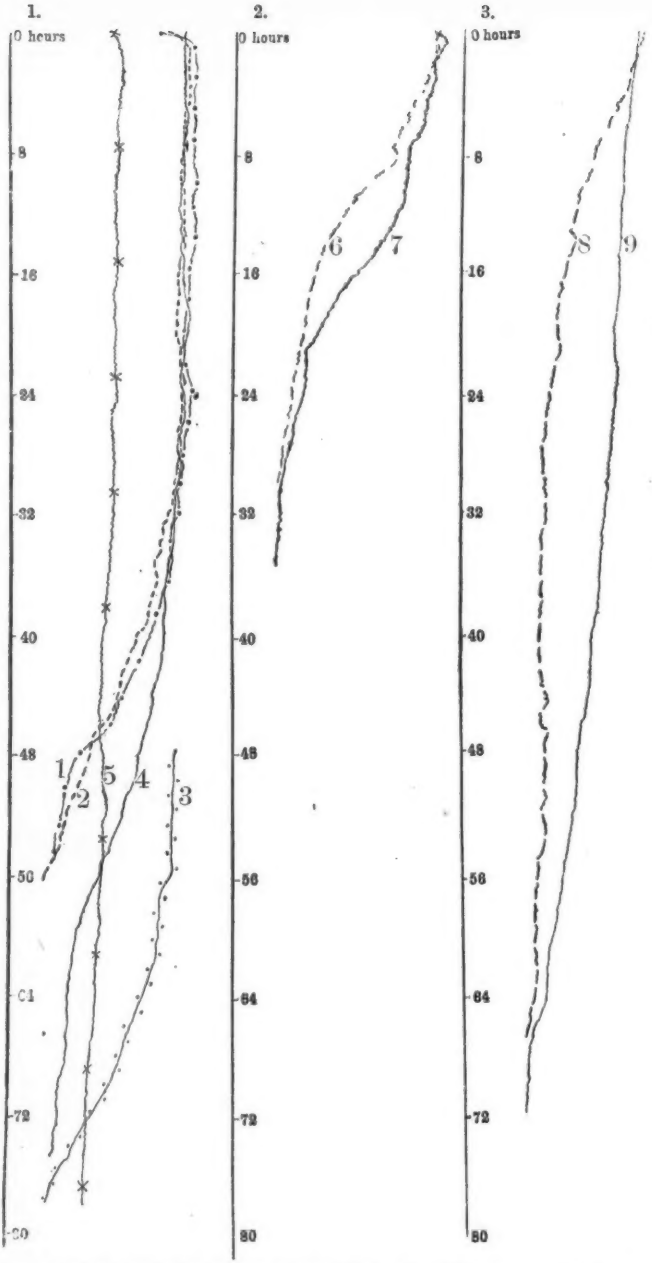


Fig. 1, Double liquid cells; 2, 3, Single liquid cells; Series 1, 2, 6, 8, bichromate of potash; 3, 4, 7, 9, bichromate of soda; 5, sulphate of copper, Daniell's.

either the expense or care of the battery is an element to be considered, the superiority of the soda cell would be especially felt.

In the case of the single liquid bichromate cells also, the superiority of the sodium salt seems to be maintained, though it is more difficult to form a correct judgment from the records of these cells, owing in part to the greater irregularity of successive records, and in part also to the fact that the greatest and most marked fall in the strength of the current occurs during the first hours of the records, while in the double liquid cells the reverse is the case, the most rapid fall occurs during the last hours and thereby indicates more accurately the close of the record. Figures 2 and 3 give several of the single liquid records, the conditions of which are contained in the following table:

Single Liquid Cells.

	Depolarizer.	External resist.	Hours before exhaustion.
Series 6	Bichr. of potash	8 ohms	29
Series 7	Bichr. of soda	8 ohms	35
Series 8	Bichr. of potash	35 ohms	67
Series 9	Bichr. of soda	45 ohms	71½

Though the difference in the number of hours before exhaustion in the two cells, as indicated by the above table, is not so great as in the double liquid cells, a glance at the records shows that the weakening of the current in the case of the potash cells was more sudden, and that it took place earlier than in the soda cells, so that the average strength for the whole time was greater in the latter cells.

An interesting question arises as to the cause of the greater power of the bichromate of soda. Both the bichromate batteries belong to the general class which provides oxygen to unite with the hydrogen set free at the negative electrode. The question, therefore, resolves itself into this: which salt can provide the greater amount of oxygen to unite with the hydrogen? Now our chemical reactions for the two salts are exactly similar, chromic acid being given off in both cases, as can be seen by writing out the intermediate reactions of (A) and (B). Thus:

(A) (1) $Na_2Cr_2O_7 + H_2SO_4 = Na_2SO_4 + 2CrO_3 + H_2O$

(2) $2CrO_3 + 6H = Cr_2O_3 + 3H_2O$

(3) $Cr_2O_3 + 3H_2SO_4 = Cr_2(SO_4)_3 + 3H_2O$

(4) $Cr_2(SO_4)_3 + Na_2SO_4 = Na_2Cr_2(SO_4)_4$

and a similar set for (B).

That salt, therefore, which can for a given weight of the solution furnish the most chromic acid will prove to be the superior. The solubilities of the two salts are as follows: at

15° C. 100 parts of water dissolve 12·5 parts of the bichromate of potash, and 83·16 parts of the anhydrous bichromate of soda. The available oxygen, therefore, in a given amount, for instance, a litre of the solution, is nearly five times as great for the soda salt as for the potash. This explanation, it seems to me, will go far toward accounting for the superior constancy of the soda cell.

In the appended table are contained the above results, and others computed with a view of comparing the two bichromates with other depolarizing agents of the same general class. The first column gives the per cent of oxygen in one molecule of each of the tabulated substances which is available for combination with the hydrogen set free; thus, in bichromate of potash, three atoms of oxygen, or ·1629 of the total weight, are available. The third column gives the cost of obtaining a kilogram of oxygen from each of the oxydizers. In these columns the fact that the bichromate of soda is hydrous increases the total molecular weight, and thereby lowers the per cent of available oxygen. In the last column is contained the amount of available oxygen in a saturated solution of each of the soluble depolarizers. As is seen from the table, bichromate of soda stands far ahead of the others in the last respect, giving 8·52 per cent of available oxygen from a saturated solution of the salt:

	Per cent of available oxygen in one molecule.	Number of kilograms to produce one kilo of oxygen.	Cost of producing 1 kilo of oxygen.	Solubility: 100 parts H_2O dissolve at 15° centigrade.	Per cent of available oxygen in a saturated solution.
Bichromate of potash,	·1629	6·138	$2·03	12·5	.01808
Bichromate of soda,	·160	6·25	1·65	anhydrous 83·16	·0852
Peroxide of manganese,	·092	10·87	1·92	insoluble.	
Permanganate of potash,	·253	3·95	3·34	6·25	·0142
Nitric acid, C. P.,	·254	3·93	2·59		

From this table it is seen that the bichromate of soda compares very favorably with the other depolarizers in all those respects which are essential for a good battery. The great solubility and large amount of available oxygen indicate great possibilities for this salt.

This table might be much extended, but, owing to the complicated nature of the chemical actions which take place in many batteries, our knowledge in this direction is very limited and consequently we cannot proceed far.

Electro-motive force.

The electro-motive force of the soda cell I obtained by the open-circuit method of comparison, by means of an electrometer, with a standard (Daniell's siphon) battery. With one

cell of this battery as the unit, the electro-motive force of the soda cells tested was as follows:

	1·887 volts.
	1·884
	1·908
Average.....	1·893

The electromotive force of the potash cell in the same way was found to be 1·852, while that of the ordinary Daniell's cell —12 parts of water to one of sulphuric acid—was 1·059 volts.

Resistance.

Lodge's method,* a modification of Mance's method, was used in determining the resistance of the cells; a condenser, in some cases of one-third of a microfarad, and, in others, of a little over a microfarad in capacity, being used. For the soda cell, the resistance was found to be:

	·494 ohms.
	·504
	·495
	·494
Average.....	·4967

Likewise for the potash cell, ·468 ohms was the resistance. The resistances of both cells could undoubtedly, if occasion should demand it, be reduced.

From the foregoing it is seen that the bichromate of soda cell is a most efficient cell; its effectiveness, however, could be materially increased, I believe—at least, as far as its constancy is concerned—by interchanging the positions of the electrodes with their surrounding liquids, after the fashion of the Fuller cell; that is, placing the zinc and sulphuric acid inside the porous cup, and the carbon, with a much increased quantity of the depolarizing mixture, outside the cup.

Jefferson Physical Laboratory, Harvard University, June, 1886.

* See Phil. Mag. Supplement, June, 1877, p. 515.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a new Universal chemical Spectroscope.*—A new form of spectroscope has been devised by G. Krüss, which is well adapted for the work of the chemical laboratory, both qualitative and quantitative.* Its fundamental form is that of the Bunsen and Kirchhoff instrument; but a variety of modifications and additions have been made, to render it available as a universal spectroscope. An upright pillar supports a table on which rests the prism, and which carries the observing, collimating and scale-telescopes. The collimating telescope has no draw-tube. It is provided with two slit-plates, one of which carries the ordinary single slit for qualitative purposes, the other the double slit of Vierordt for quantitative work. These slits are strictly parallel to the axis of the prism and are opened and closed symmetrically on the two sides of this axis, by micrometer screws, whereby the width of the slit may be determined. The knife edges of these slits are made of platinum and are so accurately worked that no horizontal lines appear in the spectrum even when the slit is open by only one or two divisions of the micrometer-head (0·002 to 0·004^{mm}.) Two prisms are provided; one a simple flint prism of 60° of a dispersion of 4° 18′ between A and H_2, the other a so-called Rutherfurd prism, having a dispersion of 8° 2′ between the same limits. By an automatic device the prism is kept at the angle of minimum deviation for the part of the spectrum under observation. The scale is fixed in its telescope so that it is in the principal focus of the object glass and so that its 100th division comes midway between the D lines. The observing telescope magnifies about seven diameters. By means of a micrometer screw with a divided head, it is moved in a horizontal plane about the vertical axis of the instrument, the amount of motion being measured by an index moving over a graduated arc upon the end of the fixed arm carrying the telescope. The value of the divisions on the micrometer head in terms of the graduations upon the arc, and the value of these in terms of the scale divisions, are easily determined. Moreover, this telescope has a micrometer eyepiece; so that spectrum measurements may be made between two colors whose wave-lengths differ by only 0·000 000 000 015 millimeter. The slide which carries the cross wires of this micrometer carries also the Vierordt slit, whose width is adjustable by the same screw that moves these cross wires. The author thinks that the results obtained by this instrument when used as a spectrophotometer, are fully equal to those obtainable with polarizing instruments.—*Ber. Berl. Chem. Ges.*, xix, 2739–2745, November, 1885. G. F. B.

* Constructed by A. Krüss of Hamburg.

2. *On the Decomposition of Glass by Capillary water-layers containing Carbonic acid.*—Two years ago, BUNSEN published the results of some experiments which he had made on the condensation of carbon dioxide gas upon the surface of glass (*Ann. Phys. Chem.*, xx, 545). His results showed that in three years 5·135 c. c. of this gas were condensed upon each square meter. Kayser subsequently repeated the experiment in a different form and obtained different results; whereupon Bunsen reëxamined the subject and showed that his glass fibers were not perfectly dry, and that a part of the observed absorption was due to this capillary water-layer. On taking the apparatus down, Bunsen analyzed the glass fibers on which the action had taken place. Under ordinary conditions carbon dioxide does not attack glass, but it is quite possible that so concentrated a solution of carbonic acid as existed in these capillary layers, might have some action. The analysis showed not only that the glass had been acted on, but that this action had been unexpectedly great. A weight of 49·543 grams of glass fiber gave to cold water sufficient sodium carbonate to yield on the addition of hydrochloric acid and evaporation, 0·8645 gram sodium chloride. From the composition of this glass, determined before the experiment, it appears that during the course of the observations—109 days—5·83 per cent of the entire weight of the glass must have been thus decomposed. The suggestion is an obvious one that possibly all the absorption, which Bunsen observed, might have been due to the formation in this way of sodium carbonate. But he shows that of the total volume of gas absorbed by the entire mass of glass, 236·9 cubic millimeters are set free again on heating. If combined as hydrosodium carbonate, the quantity of sodium found on analysis would require only 165·2 cubic millimeters, leaving 71·7 cubic millimeters to be otherwise disposed of. In view of the fact that pure water may also be expected to act on the substance of the glass, it is evident that glass is not a suitable material for experiments on capillary absorption.—*Ann. Phys. Chem.*, II, xxix, 161; *Ber. Berl. Chem. Ges.*, xix, 729, (*Ref.*) November, 1886. G. F. B.

3. *On the Properties and Constants of Germanium.*—WINKLER has communicated some additional facts concerning his new metal, germanium. When obtained, either by reducing the oxide in a current of hydrogen or by gently igniting a mixture of the oxide and starch, and then fusing the gray powder under borax, the metal appears of a grayish-white color, having a brilliant metallic luster and crystallizing in well formed regular octahedrons. It melts at a somewhat lower temperature than silver, 900°, and volatilizes at a slightly higher one than this. It expands on solidifying, and crystallizes. Its specific gravity is 5·469 at 20·4°. Before the blowpipe it fuses to a globule which evolves white fumes and explodes, as does antimony. It is insoluble in hydrochloric acid, soluble in aqua regia, and is converted by nitric acid into the white oxide with evolution of nitrogen dioxide. Concentrated sulphuric acid converts it into a

sulphate soluble in water, with evolution of sulphurous oxide. It is not attacked by potassium hydrate. Its atomic weight, estimated by titering the chlorine contained in the tetrachloride, by the method of Volhard, was found to be 72·32 as a mean of four experiments. (Lecoq de Boisbaudran, it will be remembered, calculated the atomic weight from the two characteristic lines in its spectrum, $\lambda=468$ and $\lambda=422{\cdot}6$, and found it to be 72·31 and 72·27, by two different methods, (*C. R.*, cii, 1291)). The position of germanium is that of the ekasilicium in Mendelejeff's table, for which he predicted an atomic weight of 72 and a specific gravity of 5·5. Its specific heat as determined by Nilson and Peterson, is at 100°, 0·0737; at 211°, 0·0772; at 301·5°, 0·0768; and at 440° 0·0757; the corresponding atomic heats being 5·33, 5·58, 5·55 and 5·47 respectively. These temperatures are the boiling points of water, nitrobenzene, diphenylamine and sulphur. The specific heat of the dioxide is 0·1293 between 0° and 100°. The vapor density of $GeCl_4$ is 7·43 and that of the iodide 20·43. Its spark spectrum shows one line in the orange, one in the yellow, four in the violet and twelve in the green and blue. Its compounds are characterized by their solubility and volatility, but they do not color the Bunsen flame. Two oxides, GeO and GeO_2 are described, and the corresponding sulphides and chlorides. Also GeI_4. The best test for germanium is the precipitation of the white sulphide GeS_2 upon the addition of mineral acids in excess to its solution in alkaline sulphides. This separation is so complete that it may be used quantitatively. For this purpose, the alkaline solution of germanium is mixed with ammonium sulphide, precipitated with dilute sulphuric acid in excess and saturated with hydrogen sulphide. After 12 hours standing, it is filtered off and washed, the precipitate is washed from the filter and extracted with ammonia. The ammoniacal solution, with the wash water are evaporated to dryness in a weighed porcelain dish, the main precipitate moistened with sulphuric acid added thereto and the excess of acid evaporated. After ignition the residue is treated with nitric acid, again ignited, digested with ammonia to remove the last trace of sulphuric acid, and the strongly ignited oxide weighed. To separate this metal from tin, arsenic and antimony, the author dilutes the solution to a definite volume, boils a measured portion with excess of normal sulphuric acid and determines by titering back the excess of acid required to exactly neutralize the entire solution. This amount is then added, the solution allowed to stand 12 hours, the precipitated sulphides are filtered off, the filtrate is evaporated to a considerably smaller volume, treated with ammonia and ammonium sulphide and precipitated by the addition of an excess of sulphuric acid and the passage of a current of hydrogen sulphide. This precipitates germanium sulphide pure. Argyrodite, in which this element was discovered contains Ag 74·72, Ge 6·93, S 17·13, Fe 0·66, Zn 0·22 and Hg 0·31 per cent. It is a sulpho salt of the formula $(Ag_2S)_2 GeS_2$.—*J. pr. Ch.*, II, xxxiv, 177–229; *Ber. Berl. Chem. Ges.*, xix, 652 (Ref.) Nov. 1886. G. F. B.

4. *On the distinction between spectral lines of Solar and Terrestrial origin.*—In a communication to the Physical Society, London, June 12, 1886, Professor M. A. CORNU calls attention to a method which allows one to distinguish instantly between solar lines and those due to the earth's atmosphere in the solar spectrum. This method is based upon a principle due to M. Fizeau, (Ann. de Chim. et de Phys., 4 série, t. xix, p. 211), that of the displacement of the spectral lines emitted by a source which is in absolute or relative motion. Professor Cornu shows that we shall have a variation of wave length equal to $\pm \frac{\lambda}{150{\cdot}000}$, + or − according as we take the same radiation at the eastern or western end of the solar equator, estimating the displacement in reference to the two D lines. It is found that the double displacement amounts to $\frac{1}{62{\cdot}4}$ of the distance between the two D lines. This displacement can be readily measured by the use of Thollon's prisms or Rowland's gratings. The experimental method consists in causing the image of the two extremities of the solar equator to fall alternately on the slit of the spectroscope. To effect this the beam of light passes through a condensing lens which produces in the plane of the slit a sharp image of the solar disk. A displacement of the lines of the spectrum due to the sun alone is produced by substituting one limb of the sun for the other, while the positions of the telluric lines are unaltered. Professor Cornu gives in detail the precautions which must be taken in the comparison. By causing the collecting lens to oscillate two or three times a second, the displacement becomes more evident. The distinguishing of the lines is then easily accomplished. If the line remains immovable under this shaking process it is one belonging to the earth's atmosphere, if it oscillates it is a solar line. Professor Cornu gives a map of Angström's group. He indicates the telluric nature of a certain number of lines beyond the band 8, and shows that the line 1474 of Kirchhoff is a solar one. Since it oscillates we may conclude that the vapor which absorbs the radiations of which it takes the place is carried round by the rotation of the sun, and he shows that physicists and astronomers have now a method which will enable them to tell at a glance whether a spectral line belongs to the sun or the earth. —*Phil. Mag.*, Nov. 1886, p. 458. J. T.

5. *New form of Galvanometer.*—In Wied. Ann., xxiii, p. 677, 1884, Herr Rosenthal described a very sensitive galvanometer, in which the poles of the suspended magnet were brought very near the coils. Hr. J. Kollert has constructed a similar instrument which is more sensitive than that of Rosenthal. It consists of four coils whose axes all lie in the same horizontal plane; and the coils are placed radially in this plane. The magnets are made out of very thin watch spring in the form of arcs of a circle. Two such arcs are placed at the extremity of a straight arm which is suspended horizontally from its middle point. The ends of the magnets can thus pass into the centers of the radial coils.

A current of ·000,000,001 A. gives a deflection with suitable distance of reading telescope of 0·7 of a scale division.—*Ann. der Physik und Chemie*, No. 11, 1886, p. 491. J. T.

6. *Metallic deposits formed by electrical discharges.*—Professor Wright of Yale College described in this Journal, vols. xiii and xiv, 1877, a method of obtaining very thin deposits of metals by electrical discharges in rarefied air. The subject has been taken up anew by Hr. Bernard Dessau, who investigates the interference phenomena produced by such thin layers. Generally these layers are thicker directly opposite the electrode from which the metallic particles are thrown off. Hence a cone is formed of a very small altitude. The deposits showed in reflected light colored interference rings. The dispersion in the metals platinum, iron, nickel and silver, the author calls normal, and that with gold and copper abnormal. The cross of double refraction was also noticed in reflected light.—*Ann. der Physik und Chemie*, No. 11, 1886, pp. 353–376. J. T.

7. *Electricity arising from the condensation of vapor.* — It has been maintained by Palmieri and others that the condensation of vapor results in the production of an electrical charge. Hr. S. Kalischer has renewed his investigations upon this point and believes that he has proved that no electricity results from such condensation. Atmospheric vapor was condensed upon a vessel coated with tin foil, filled with ice, carefully insulated and connected with a very sensitive electrometer. No evidence could be obtained of electricity.—*Ann. der Physik und Chemie*, No. 11, 1886, p. 407. J. T.

II. Geology and Mineralogy.

1. *The Charleston Earthquake.*—The earthquake which occurred in the southeastern United States on the evening of Aug. 31, 1886, and which will doubtless always be known as the Charleston Earthquake because of the great destruction caused by it in that city, is being made the subject of careful study by the seismologists of America, and there is good hope that valuable results for the future of seismology may issue from their work. Rarely if ever has a better opportunity for study been presented. The primary shock was of sufficient intensity to destroy many buildings in Charleston and vicinity and was felt over a land area of nearly 800,000 square miles, extending from the great lakes to the gulf and from beyond the Mississippi to the Atlantic, being felt also very slightly in the Bermudas and in Cuba. This large area is covered with a network of telegraph lines whose offices were ready at once to collect and communicate the news of the shock; and the standard time is very generally in use, so that the records of time give fair promise of accuracy and are readily comparable. Our country is also supplied with active newspapers which put on record with care and in full detail the phenomena of the shock.

To these general means of information are to be added others set in operation for this special occasion. Major Powell, the Di-

rector of the United States Geological Survey, promptly took up the matter and sent W. J. McGee, a geologist of the Survey, to personally examine the ground. At the request of the Survey the United States Signal Service also sent Professor T. C. Mendenhall, of their corps, a former resident of Japan and a member of the Seismological Society there. These observers spent a week in the vicinity of Charleston, and brought back many valuable data, besides a series of photographs of injured buildings and displaced monuments. A competent person was also left on the ground to continue their observations.

A series of questions was promptly distributed through the public press and by special circular, and the personal letters received by the Geological Survey in reply already number several hundred and are still receiving additions. The Signal Service, through its observers, has a large amount of information which is also open to the Survey, while the other departments of the government, as the Hydrographic Office, the Light House Board, etc., have each contributed whatever information was in their hands.

It will be seen therefore that the mass of information in regard to the Charleston Earthquake which is accumulating in the hand of the Geological Survey, both in amount, in careful detail, in number of contributors and in area covered, is likely to far surpass that gathered in respect to any previously studied earthquake. Of course in such a mass of material, coming from all sorts of persons, much is included that has little scientific value; but there are also many careful reports from competent scientific observers, and the results should be as good as can ordinarily be obtained from non-instrumental observations. Indeed the one thing to be regretted is, that the Earthquake Commission had not yet perfected their plans for establishing a series of seismoscopes; although it is doubtful if the area selected for them would have included the southern Atlantic States even if they had been ready for use.

It will be evident, from what has been said, that much time and labor are needed to sift from such a collection what is authentic and valuable and to collate and compare the records so obtained, before any attempt can be made to formulate results. On this work the Geological Survey is now engaged, certain of its members having occupied nearly all their time for the past three months in the clerical labor involved, but it will still take months of steady labor before the final results will be ready for publication.

Meantime some things have appeared in print which deserve mention here, although their full discussion must be reserved for another time. In Science, No. 188, Sept. 10, 1886, a map of coseismals, or lines of equal times, was published as prepared by Everett Hayden of the Geological Survey, which however can only be regarded as a first rough approximation. In the U. S. Monthly Weather Review for August, 1886, issued in October,

the data in the hands of the Signal Service are summarized by Professor Mendenhall in a brief report, accompanied by a map of Isoseismals, or lines of equal intensity, which show some curious deviations from uniformity. Science No. 199, Nov. 26, 1886, also contains a map of isoseismals and coseismals prepared for the Philosophical Society of Washington, by Edward Hayden, from data, mostly correspondence, in the hands of the Geological Survey up to October 23. The isoseismals of this map are considerably more irregular than those given by Mendenhall, although the two maps agree in the general form of the curves. They suggest some interesting relations with the geology of the country which it is yet too early to enlarge upon. They indicate however a focus or epicentrum lying somewhat north of Charleston. During September, Science also published copies from some of the photographs brought home by McGee.

The earthquake did not consist of a single isolated shock, but the great shock of August 31 was preceded by perceptible tremors on the 27th and 28th and has been followed by almost daily shocks, mostly of minor intensity, even up to the date of this writing, one being reported in to-day's paper. C. G. R.

Princeton, N. J., Nov. 30, 1886.

2. *Naturally Reduced Iron;* by J. B. TYRRELL, of the Geological Survey of Canada. (Communicated to this Journal).—On the North Saskatchewan River, about seventy miles above the town of Edmonton, in the district of Alberta, in rocks of Laramie age, an almost horizontal bed of lignite may be seen cropping out at intervals in the river-bank for several miles, overlaid by dark gray clay-shales and gray and yellow soft argillaceous sandstones containing nodules of clay ironstone. Although none of the nodules from this particular locality have been analyzed, similar ones from Edmonton, obtained from beds of the same formation, were found to be essentially carbonates of iron containing 34·98 per cent of the metallic iron.

The seam of lignite has been completely burned out over a considerable area, leaving the surface covered with a bed of debris of ashes, clinkers and burnt clay, in places to a thickness of twenty feet, supporting at present a thick growth of grass and underbrush. From this mass of burnt clay and cinders pieces of metallic iron can be readily picked out, weighing, in some cases, as much as fifteen or twenty pounds, doubtless derived from the nodules of ironstone mentioned above, which had been reduced to the metallic state by the heat caused by the burning of so large a body of lignite.

Most of the pieces of iron observed were very much rusted and fell to pieces readily on being struck with the hammer, though when scratched with a file they everywhere showed a bright surface.

Ottawa, Dec. 11th, 1886.

3. *A Partial Report of the Geology of Western Texas;* consisting of a general geological report, and a journal of geologi-

cal observations along the routes traveled by the expedition between Indianola, Texas, and the Valley of the Mimbres, New Mexico, during the years 1855 and 1856: with an appendix giving a detailed report of the geology of Grayson County, Texas; by Professor G. G. SHUMARD, Assistant State Geologist of Texas (1858–1860.) Austin, Texas: State Printing Office, 1886. Published and edited by H. P. BEE, Commissioner of Insurance, Statistics and History. 145 pages 8vo, with plates.—The scarcity of knowledge concerning the details of geological structure in the vast area embraced within the political bounds of the State of Texas is proverbial, and so inextricably is the little knowledge that we possess involved in controversy that any light upon the subject, however feeble, is always welcome at this time. The appearance at this late day of a volume giving the detail of scientific exploration that took place over twenty-five years ago in that region has a double value. In the first place it indicates a revival of interest in geological investigation by a State government, in which a once strong desire to make known its resources in a scientific manner, was almost entirely killed by the wrangling among themselves of the scientific men employed to carry out its intentions. The knowledge of large regions of hitherto unpublished territory which it brings to us is specially welcome.

The two brothers, Benjamin F. and George G. Shumard were ardent lovers of scientific exploration, and their names will always be inseparably connected with the scientific history of the southwest. The former was more inclined to descriptive paleontology, and the latter to traveling and collecting, the results of his labors often having been turned over to his brother for study and publication. He accompanied the government expeditions into and across the plains of Texas and New Mexico, and especially those conducted by Captain Randolph B. Marcey, and Lieut. Geo. B. McClellan to the head waters of the Red river, in 1852, and Captain Pope's expedition for boring artesian wells on the Staked Plains. In the year 1858 Dr. B F. Shumard was appointed State Geologist by the Governor of Texas, and he, in turn, appointed his brother to the position of Chief Assistant, and assigned him to that vast region of northern Texas adjacent to Red river. These gentlemen began their labors in a country at that time exceedingly unpropitious for successful investigation, owing to the scarcity of population, the hostility of the Comanches and allied tribes, and the absence of rail or water communication. Just as the organization was reaching a period when it was ripe for the publication of results, a State election brought into power a new political party. An ambitious subordinate poisoned its executive against the Shumards, and they were suspended, their collections taken from them, and their manuscripts lost or destroyed. The volume before us gives more of the results of the survey than any other publication made by the State of Texas. It is true that Dr. B. F. Shumard published in the Transactions of the St. Louis and Boston societies, up to the time of his death,

fragments of his labors as State geologist, but never, until the present volume, in the year 1886, did the State government publish for distribution any of the results of his survey.

The volume will be of interest at the present day chiefly for purposes of compilation. The stratigraphical deductions of the Shumards are now known to have been erroneous, and their sections of the Cretaceous strata of Texas, as published by Dr. B. F. Shumard in 1860, most assuredly place the bottom of the Texas strata on top, the top in the middle, and all the other subdivisions equally out of place. Mr. Jules Marcou,* in 1861, called attention to this discrepancy, and published an approximately correct ideal section; but his then recently published erroneous opinion concerning the alleged Jurassic age of certain Texas strata prevented this criticism from carrying with it the weight it deserved.

The portion of the work entitled a "Detailed Report of the Geology of Grayson County," is especially misleading, for it leads the reader to believe that in that vicinity is to be found nearly every representative of the series from the Tertiary to the base of all the Cretaceous strata of Texas. This is not the case, however, for the writer has examined the whole region in person, and found that Dr. Shumard's Tertiary is Cretaceous, and that his "Lower Cretaceous" is really the very top of the great group of the period which once covered Texas west of that county, and which, in it, is partially covered by the southwestern prolongation of Hilgard's Mississippi series.

It is to be hoped that the State of Texas will not only publish all the results of the old Shumard survey that it can lay hands upon, but that it will some day resume the geological work which it once began with so much earnestness. R. T. HILL.

4. *The Washoe Rocks*, by G. F. BECKER. (Bull. California Acad. Sci., Nov., 1886.—The views of Mr. Becker on the Washoe Rocks, as published in 1883, are briefly presented in a notice of his paper in vol. xxvi of this Journal (p. 479). A subsequent detailed study of Mr. Becker's sections of the rocks by Messrs. Hague and Iddings, in connection with an earlier study of the region by Mr. Hague, led them to different views, as stated in vol. xxx of this Journal (p. 388), 1886, these authors making out that several of the igneous rocks, regarded by preceding authors as independent in age and mass, were of the same age and mass, although varying from scoriaceous to granitoid in texture. To the latter article Mr. Becker replies in his recent paper.

Mr. Becker states that he has new evidence of the existence, in the region, of diabase as a pre-Tertiary rock, and of the fact of two distinct out-flows of pyroxene-andesite of different periods. On the first point he mentions that six miles from the Comstock lode, in a Jura-trias sediment, diabase pebbles occur which are lithologically like the diabase of the east wall of the lode; and

* Proc. Bost. Soc. Nat. Hist., viii, 1861.

that the two localities are in the same lithological district. He says that it is not necessary or possible to prove, that the pebbles came from the Comstock locality; and recognizes, in a following paragraph, the fact that the distinctions between the porphyritic diabase and the augite-andesite of the Comstock walls "are somewhat refined" and in many cases not distinguishable in hand specimens. Still he believes that the distinctions are sustained by his observations. Other arguments are presented in order to prove succession in periods of out-flow in the different kinds of rocks, and sustain the order:—porphyritic diabase, hornblende-andesite, pyroxene-andesite, later hornblende-andesite, pyroxene-andesite. The evidence given is partly lithological, and relates to rocks which have, as is implied, these perplexing transitions, so that it is set forth as probable rather than positive. The similarity in the rock of the two walls, claimed by Messrs. Hague and Iddings, is remarked upon adversely, but with the admission that the question is difficult to decide.

Mr. Becker states that he found the diorite at the 3,000 foot level in the Comstock lode, identical with that at the top, and concludes that the crystallization does not vary with the depth; and the same for the diabase; and in a belt at the surface about 7,500 feet above the Sutro tunnel, he failed to find a serial progress in degree of crystallization. Other points also are considered, and in general his former positions are not yielded.

On the main question, independent of Washoe, the difference between these observers appears to be small. For Mr. Becker says (p. 95) that "it has never appeared to me that a distinction between pre-Tertiary and Tertiary eruptions was a natural one," but "an artificial substitute;" yet he adds "which it would be unwise to abandon until some available principle distinguishing little eroded from deeply eroded rocks is discovered and thoroughly established." Allowing that the determination of the facts by direct observation should precede the attainment of the needed principle, and there would be agreement here also. The region is one of difficult investigation on account of the natural transitions in the rocks, transitions also from the alteration of pyroxene to hornblende, and the obscurity over the larger part of the exposed surfaces on account of the deep alteration and especially along the walls of the lode. Mr. Becker presents his arguments cautiously, making them probable rather than positive, and they indicate that he regards the question as still an open one. They appear to be insufficient, under the uncertainties, to set aside the improbability of his conclusions.

Whatever uncertainty may exist with regard to the relations of the Washoe rocks, the principles deduced from them by Messrs. Hague and Iddings appear to be placed beyond reasonable dispute by later investigations in Great Britain and Italy.

5. *Volcanic Glass changed by heat alone to Pumice.* In a paper on Marekanite, pearly glassy balls of volcanic origin (Geol. Mag., June, 1886), Professor J. W. Judd shows that the amount

of volatile matter present is large enough to convert the glass, when heated to whiteness, into cauliflower-like masses which are true pumice. The same author in a later paper "On the volcanic rocks of the Northeast of Fife, Scotland," states that a dacite-glass, when carefully dried at 110° C. and then weighed was found, on ignition, to have lost 8.90 p. c. of its weight; and when fragments were heated in a flame urged by a powerful blast they swelled up into cauliflower-like excrescences, 8 to 10 times the original bulk. The obsidian of Krakataô (a porphyritic enstatite-dacite glass) acted in the same way, yielding a dirty-white pumice, "almost undistinguishable from the natural pumice which was ejected from that volcano during the great eruption of August, 1883." The latter paper is in Q. J. G. S., Aug., 1886.

6. *North America in the Ice Period;* by J. S. Newberry. (Pop. Sci. Monthly, Nov. 1886).—Dr. Newberry reviews in this paper, the facts with regard to the general distribution of the drift in North America and illustrates the subject by two maps, one of North America, and the other of the United States east of the Rocky Mountains. He also gives the results of his personal observations, especially in Western America. His map represents glaciers as descending along the Rocky Mountains to the northern part of New Mexico, and to about the same parallel on the Sierra Nevada. The conclusions drawn from the facts are the following: that the North American ice envelope covered nearly or quite half of the continent; that the Ice period was a cold period; that it was a result of general and not of local causes, of cosmical agencies, and not of topographic or even terrestrial. With regard to the view that no lowering of the temperature in the glacier regions was necessary to explain the facts, Dr. Newberry mentions as one among many facts, that on the Cascade Mountains, Oregon, precipitation of both rain and snow is at present very copious, the snow-line falling to 7,000 feet above the sea-level, and yet there is no ice where great glaciers formerly existed; the precipitation remains; the snow-fall remains; but the glaciers are gone "because of the high annual temperature." A depression of temperature which should cause the rain-bearing winds from the Pacific to do all the year what they now do only in winter, that is, heap up snow on the highlands"—would make an annual accumulation; and thus "the slopes and valleys would soon be occupied by glaciers as they were in former times."

7. *Geological map of the United States;* by C. H. Hitchcock. —Professor Hitchcock has a paper, accompanying a colored geological map of the United States, in the Transactions of the American Institute of Mining Engineers. The map measures 18 inches by 28. It is based, as is stated, on the map published in the 5th Annual Report of the Director of the U. S. Geological Survey, prepared by Mr. W. J. McGee, and is intended "to illustrate the schemes of coloration and nomenclature recommended by the International Geological Congress." The map is handsomely printed (by J. Bien) and the effect of the arrangement of colors is excellent

Professor Hitchcock gives a brief résumé of the history of American geological maps, and the special characteristics of each, in the following order: Maclure's, 1817; James Hall's, 1843; Lyell's, 1845; Edward Hitchcock's, 1853; J. Marcou's, 1853, and again in 1855; H. D. Rogers, published at Edinburgh, in Keith Johnson's Physical Atlas, 1856; Hall & Lesley's, published in vol. i of Emory's Rep. United States and Mexican Boundary Survey, 1857; Logan & Hall's grand map, published 1866, as the Geological map of Canada—the only map hitherto published which compares in style, magnitude and detail with those of European Geological Surveys; C. H. Hitchcock and W. P. Blake's map, in the United States publications of the Ninth Census, 1872; C. H. Hitchcock's large map of 1881, published by Julius Bien; McGee's map, U. S. Geol. Survey, of 1885.

In a note, Professor Hitchcock states that Mr. J. Marcou's extensive "Mapoteca Geologica Americana," published as No. 7 of the Bulletins of the U. S. Geological Survey, has an important omission, in making no mention of the great Canada map of Logan & Hall. The paper states also the reasons of the author for disagreeing with the author of the "Mapoteca" in other respects.

8. *Tertiary Fossils: Geological Survey of Alabama*, 1886.—This volume contains a *Preliminary Report on Tertiary Fossils of Alabama and Mississippi*, by T. H. Aldrich, and *Contributions to the Eocene Paleontology of Alabama and Mississippi*, by Otto Meyer.—The former paper is illustrated by six lithographic plates, and the latter by three. The excellent work of Messrs. Aldrich and Meyer is doing much to remove the doubts and obscurities connected with the Gulf-border Tertiary fossils. Professor E. A. Smith, the State Geologist, opens the volume (of 60 pages) with a brief account of various stratigraphical sections of the Tertiary. In his preface he mentions that this Bulletin, No. 1, "is the first contribution toward a work, undertaken by Mr. Aldrich, illustrating the paleontology of the Tertiary formation of Alabama, and that the work, with its plates and other illustrations, is to be the *gift* from Mr. Aldrich to the State of Alabama. It will embrace figures and descriptions of all the shells found in the Tertiary deposits of the State, and include reproductions of the figures already published elsewhere." "Mr. Aldrich furnishes gratuitously not only the text of his article but also provides, at his own expense, the entire printed edition of the plates illustrating both his own and Dr. Meyer's articles."

9. *Geological Survey of Alabama*, Eugene A. Smith, Ph.D., State Geologist. *On the Warrior Coal Field*, by H. McCalley, Chemist and Assist. Geologist, Montgomery, Ala., 572 pp. 8vo, 1886.—This volume is devoted to a detailed description of the principal coal field of Alabama. The number of consecutive beds in this extensive coal field is stated to be 35; of which 15 are over 2½ feet thick and 6 of 4 feet or over. It is stated that the coal beds appear to thin toward the northwest. An estimate puts the amount of available coal in the Warrior coal region from the

seams over eighteen inches in thickness, above 108,000,000,000 tons, which is "three times that of the estimated available bituminous and semi-bituminous coals of Pennsylvania."

10. *Geological Report of New Jersey for* 1885. 228 pp. 8vo. —Speaking of the junction of the Potsdam sandstone and Archæan in New Jersey, at two localities in Sussex county, Professor Cook states that the actual plane of contact is obscured by the occurrence of so much feldspar in the sandstone as to present the appearance of a gradual transition into the older rock. Besides the general feldspathic character of the Potsdam, fragments and masses of the Archæan are imbedded in it. These facts are similar to those that have been reported from the vicinity of the junction both north and south of the Archæan, on the west side of the Hudson River. They tend to show that the Triassic was a valley or estuary formation.

A map of Sandy Hook in the report, facing the title page, gives, beside the outline for 1885, the outlines from a survey in 1685, also in 1765, and later lines from the U. S. Coast Survey. The increase in length and breadth since 1685 has given more than four times the area it then had. A map is given of Little Egg Harbor showing, since 1841, that the drifted sands have prolonged the north point of the entrance nearly 3 m. S.W. and closed the old inlet. At Holly Beach a similar change has taken place by a southward drift of the sands along the beach, which has also shortened in the north end.

11. *Freshwater Invertebrates of the N. A. Jurassic.*—Bulletin 27 of the U. S. Geological Survey is occupied with a paper by Dr. C. A. White on the freshwater invertebrates from the Jurassic rocks of Dakota, Colorado and Wyoming. The genera of shells represented are *Unio* (7 species), *Limnæa* (3), *Planorbis*, *Vorticifex*, *Valvata*, *Viviparus*, *Lioplacodes*, *Neritina ;* and the *Ostracoda*, according to the best English authority, Professor T. Rupert Jones, to whom they were submitted, include *Metacypris Forbesii* Jones, besides other species of the same genus, *Darwinula leguminella* Forbes, and several yet undescribed species of *Cypris*. The memoir is illustrated by four plates.

12. *Modern Petrography, an account of the application of the Microscope to the study of Geology ;* by George H. Williams. 35 pp. Boston, 1886 (Monographs on Education, D. C. Heath & Co.)—This is an interesting essay, telling of the methods of microscopical Petrography, and calculated to give to the reader something of the enthusiasm for the subject which is felt by the writer. Its usefulness to teachers is increased by the bibliography, suggestions as to instruments, etc., given at the end.

13. *Stromeyerite from Mexico.*—Dr. König has analyzed a specimen of stromeyerite from Zacatecas with the following results:

S	Ag	Cu	Insol.
15·81	50·18	33·69	0·26 = 99·94

This corresponds to the formula $(Ag, Cu)_2S$ with the ratio of silver to copper sulphide nearly 1 : 1, or exactly 47 : 53. The min-

eral occurs in imperfect prismatic crystals on quartz; the specific gravity was 6·230.—*Proc. Ac. Nat. Sc. Philad.*, p. 281, 1886.

14. *Stüvenite, an alum from Chili.*—Dr. Darapsky has recently described a series of Chilian alums derived from the abandoned mine Alcaparrosa near Copiapo. One of these occurred in slender acicular crystals, 2 or 3 inches in length. An analysis yielded:

	SO_3	Al_2O_3	MgO	Na_2O	K_2O	H_2O
$(\frac{2}{3})$	36·1	11·6	1·0	2·7	*tr.*	47·6

This corresponds to $(Na_2, Mg)SO_4 + Al_2S_3O_{12} + 24H_2O$. To this alum the name Stüvenite is given after the mining engineer Enrique Stüven. The paper from which this is taken closes with a discussion of the mutual relations of the numerous species, hydrous sulphates of alumina with potash, soda, magnesia, lime, manganese, zinc and iron.— *Verhandl. wissensch. Vereins Santiago*, p. 105, 1886.

15. *An artificial crystallized Silico-carbonate.*—Rammelsberg, who some years ago described crystals of gay-lussite obtained from soda lye at the chemical manufactory of Dr. Reidemeister at Schönebeck, has recently given an account of a silico-carbonate of alumina, lime and soda obtained from the same source. This is found in tabular crystals, which belong to the orthorhombic system. They yielded on analysis:

SiO_2	CO_2	Al_2O_3	CaO	Na_2O	H_2O
22·75	14·99	7·38	13·28	22·37	[19·23] = 100·

This coresponds to a compound of the normal silicates and carbonates of alumina, lime and soda or simply $R(Si, C)O_3 + \frac{1}{7}$ aq. This compound is particularly interesting because related to the natural silico-carbonate cancrinite. Rammelsberg suggests that the formula of cancrinite may be written $2R_2(Si, C)O_3 + 3R_4(Si, C)O4$, assuming that SiO_2 and CO_2 play the same role, as in the artificial compound described.

III. Botany and Zoology.

1. *Bulletin of the Congress of Botany and Horticulture at St. Petersburg.*—The botanists and horticulturists held an international congress at St. Petersburg in May, 1884. The *Bulletin du Congrès*, printed in 1885, has now just reached us at the close of the year 1886. It is an imperial octavo volume of 335 pages, largely in French, partly in Russian and German, with one article in English.

The latter is "*Notes on the genus Lilium*," by H. T. Elwes, the author of the sumptuous Monograph of the Lilies (which was completed in 1880), and one of the two British delegates at the Congress. The article closes with a list of the Lilies at present known, 51 species, with principal synonyms and habitat. The only species added in these last few years are three by Brossier in the last volume of the Flora Orientalis, which may not hold good. Mr. Elwes doubts whether many more are to be expected, except

from the Chino-Himalayan region. He records some interesting details respecting the cultivation and the constitutional disposition of various species; he finds it "an important point in the culture of delicate lilies, that the ground in which they are planted should be already occupied by the roots of shrubs or plants which, without overgrowing the lilies entirely, will have the effect of keeping the soil drier and more open"; he confirms what he had said "as to the extreme difficulty of raising hybrid lilies from seed," and, in view of the insufficiency of dried specimens in such plants, and the remarkable differences in the bulbs which he has pointed out, he impresses the importance of studying them in life. This he has done above all others.

Mr. Lynch, the curator of the Botanic Garden of Cambridge University, in a brief paper with some figures, explains the method of cultivating aquatic plants, such as water-lilies, which he has made so successful.

Baillon has an interesting memoir on what he terms *ovaires acropylées*, namely ovaries open at the top at the time of fecundation, and which are or may be fecundated either directly by the deposit of pollen upon the projecting or imperfectly enclosed nucleus of the ovule, as he shows in certain cases in *Rheum*, or by the growth of pollen-tubes down a pervious passage through the ovarian walls widely distant from the stigmas, as in *Passiflora*. The borders of the orifice at the apex of the ovary, between the reflexed styles, in *Passiflora cærulea*, appear to excite the growth of pollen-tubes even more readily than the stigmas themselves. For the difficulty of fecundating this species is well known; but Baillon now tells us that the French gardeners have long known how to do it, by application of the pollen to the top of the ovary between the bases of the styles! Baillon says that there are many other angiospermous plants with open ovary. Those systematists—just now in the majority—who relegate the Gymnosperms to a position far away from the other Dicotyledons, should compare all this with the structure and fecundation of *Gnetaceæ*, and reconsider.

The essay by Timarizeff on the function of chlorophyll was some time ago noticed in this Journal. So, also the paper of Maximowicz upon the vegetation of Mongolia and northern Tibet in the light of recent collections by Russian explorers.

A second communication by Mr. Lynch should not be overlooked. It is upon the tubers of *Thladiantha dubia*, which look like small potatoes, and by which this rather pretty cucurbitaceous plant propagates in the gardens freely, not to say exclusively, for the female sex is rarely seen. We took it for granted that these were true tubers, but Mr. Lynch shows that they are thickenings of roots, that they form even on the primordial root of the seedling, as well as upon secondary fibrous roots, and that the sprouts are adventitious buds. Mr. Lynch says that all the seeds he has received and raised gave rise to male plants, and that the female is unknown in England. We have had both in cultivation, but the

female soon died out, while the male, thanks to these false tubers, has become a weed.

Equally interesting to pomologists and to botanists, is a communication in Russian, by a M. Wilkins, who sends from Feringha in the province of Khiva, the figures of peach-stones, filling two folio plates, with explanations,—designed to show the presumed genealogy of the varieties: it is an instructive series. Happily, Dr. Maximowicz gives an abstract of the paper in French, and appends some notes. He remarks that while in Western Asia and Europe, where the peach is prized as a fruit, it is this which has developed so many and great variations, while in China and Japan, where ripe peaches are less esteemed (being thought unwholesome), and the tree enters into ornamental cultivation, it is the flowers which are greatly varied. A. G.

2. Minor Botanical Notes.—Mr. Maw has completed his *Monograph of the genus Crocus*, a superb royal quarto volume, with 81 hand-colored plates, maps, vignettes, &c., published by Dulau & Co., London. From Beccari we have received the second part of the third volume of *Malesia*, mainly devoted to Asiatic Palms. Part 12 of the second volume of the new (Botanical) series of the Transactions of the Linnean Society of London is occupied with a paper by Mr. Fawcett, of the British Museum, *On new species of Balanophora and Thouningia, with a note on Brugmansia Lowii;* with four fine plates.

Jahrbuch des Königl. botanischen Gartens und des botanischen Museum zu Berlin, Band iv, edited by Professor Eichler, Dr. Garcke, and Dr. Urban, has just appeared. The larger papers are by E. Fischer on the *Phalloideæ;* Loew, on the relations of insects to plants in the Botanic Garden (an extensive article, which we propose to give some account of); Wenzig on Old World Oaks; Urban, Miscellanea in the Botanic Garden and Museum and on Pollenisation in *Loasaceæ;* and Schumann, on Comparative Morphology of the Flowers in the cucullate *Sterculiaceæ*. We learn with great sorrow that Dr. Eichler's health is seriously impaired.

Recent additions to Canadian Filicineæ, by T. J. W. Burgess, forms an article of 10 pages, quarto, in the Transactions of the Royal Society of Canada, just issued.

Additions to the Flora of Washington and vicinity (i. e., additions to Mr. Ward's excellent catalogue), by F. H. Knowlton, make a pamphlet separately issued from the third volume of the Proceedings of the Biological Society of Washington.

History and Biology of the Pear-blight, by J. C. Arthur, is the thesis presented for the doctorate in science to Cornell University in June last, and now published by the author in the Proceedings of the Philadelphia Academy of Natural Sciences, 24 pages 8vo, and a plate. The whole history of this fearful blight is given in detail, the most curious fact being that it is peculiar to Atlantic North America, where it has been known for almost a hundred years. The plate gives figures of the bacterium, which, according to Professor Burrill's discovery, produces the disease; also the

zooglæa grown from it in cultivation in hay and potato infusion. The name of this destructive bacterium, given by Professor Burrill, the discoverer, was *Micrococcus amylovorus*, which, "by a typographical error" was in a reprint of the author's original paper "made to read *M. amylivorus*, a mistake which has been copied into other works," says Dr. Arthur. We should say that the latter was rather the correction of an original mistake, which should have been accepted with thanks, unless indeed the bacteriologists are *super grammaticum* and prefer to write *carnovorus* and *insectovorus* and *graminovorus*, which is not likely.

I. Freyn, of Prague, has recently published several articles on *Ranunculus*, and is engaged in a complete elaboration of the European species. In furtherance of his work he solicits exchanges with American botanists.

Acta Horti Petropolitani, tom. ix, fasc. 2, is just received. The article which most interests us is on the plants of the Commander Islands, i. e., Bering Island and Copper Island, next to the coast of Kamtschatka, being a list of the species collected by two Russian Doctors, in 1879 and 1881. To our surprise the *Bryanthus Stelleri* is not among them. Dr. Herder gives a complete enumeration and determination of George Forster's *Icones Plantarum in itinere ad insulas maris australis collectarum, cum tabulis æneis et duobus pictis*, two volumes in folio, of which the Petersburg Garden possesses an unique copy. The volume also contains the younger Regel's fine *Monographia generis Eremostachys*, with ten large plates.

Catalogus Systematicus Bibliothecæ Horti Imperialis Botanici Petropolitani, a new edition, by Dr. Herder, forms a large 8vo volume of 510 pages, with complete indexes; a valuable volume.

Sir Joseph Hooker's Primer of Botany has been issued in a third edition, revised and considerably enlarged, especially by sections on the general nature and work of plants, on their tissues, their food, assimilation, etc. The primer now has 143 pages, about twenty more than in the second edition.

Mr. N. L. Britton, of the Torrey Herbarium, has contributed to the Bulletin of the Torrey Botanical Club, vol. xiii, no. 11, a Preliminary List of the North American species of *Cyperus*, with descriptions of new forms, a recast of the genus, with two new species, *C. Halei* and *C. Wrightii*, and several varieties. A. G.

3. *Bulletin of the American Museum of Natural History*, vol. I, No. 7, Central Park, New York.—The number for July contains the following memoirs: Description of a Squirrel, *Spermophilus tereticaudus* of Arizona, E. A. Means; Life history of *Amblystoma opacum*, and on *Scaphiophus Holbrooki* Col., N. Pike; Revised list of birds of Massachusetts and on *Colinus Ridgwayi* of Arizona (with a fine colored plate), J. A. Allen.

IV. Astronomy and Mathematics.

1. *The Argentine General Catalogue.*—This Catalogue of Southern Stars forms volume xiv of the *Resultados del Observatorio Nacional Argentino* and contains positions of southern stars observed by Dr. Gould with the meridian circle at Cordoba. In forming the observing lists the stars needed for reducing the zones and the stars of the Uranometry were first disposed of, then those stars remaining of Lacaille and Brisbane, and the bright southern ones of Lalande. To these were then added stars from Gilliss, Yarnall, Moesta (2), Stone's Maclear, Ellery and from the Cordoba Zones. Most of the stars brighter than $8\frac{1}{2}$ magnitude must have been observed, especially most of those south of the parallel 23° S. The current numbers run to 32,448, though clusters that are added will increase the total by more than a thousand stars. These figures show the magnitude of Dr. Gould's work, and the importance of the catalogue in Southern Stellar Astronomy. It is very rare that there is occasion to take note of such a remarkable contribution to the science.

2. *Theory of Magnetic Measurements with an Appendix on the Method of Least Squares;* by Francis E. Nipher. 94 pp. 8vo. New York, 1886 (D. Van Nostrand).—The experience of the author has enabled him to write a volume containing much that will aid other observers in the same field.

V. Miscellaneous Scientific Intelligence.

1. *Precious Stones in Nature, Art and Literature,* by S. M. Burnham. 400 pp., large 8vo. Boston, 1886 (Bradlee Whidden).—This is a handsomely printed volume, written in an attractive style and giving much information of interest to the general public. The scientific portion of the work—a small part, indeed, is not quite as accurate as might have been desired.

2. *Transactions of the Royal Society of Canada,* Vol. III, 1886. (Dawson Bros.).—This valuable volume contains, among the papers in the sections on physical, chemical and natural science: A. Johnson, on tidal observations in Canadian waters; Dr. Hunt, on a natural system in mineralogy; Dawson, on the Mesozoic floras of the Rocky Mountain region in Canada; E. J. Chapman, on a hematite mine; G. F. Matthew, on the Fauna of the St. John's Group; R. R. Wright, on the skull and auditory organs of Hypophthalmus, and others. There are also in the other sections, many papers on archæological subjects and on historical and other topics.

3. *Journal of Morphology.*—This Journal of "Animal Morphology" is announced by Ginn & Co. of Boston as to appear early in 1887. Two numbers, of from 100 to 150 pages each and 5 to 10 double plates, will be issued a year, at $6.00. C. O. Whitman of Milwaukee, Wis., is to be the editor, with the promised coöperation of many zoologists, the list commencing with the names of Dr. J. Leidy and E. D. Cope of Philadelphia.

4. *Papers of the Berkshire Historical and Scientific Society.* 136 pp. 8vo. Pittsfield, 1886.—This first volume of the Berkshire Society contains four papers: On Berkshire Geology, by J. D. DANA; On the western boundary of Massachusetts, by F. L. POPE; the Judicial history of Berkshire, by H. W. TAFT; the Early roads and settlements of Berkshire west of Stockbridge and Sheffield, by H. F. KEITH.

5. *Journal and Proceedings of the Royal Society of New South Wales*, vol. xix, 1885. A. LIVERSIDGE, Editor.—This volume of the Royal Society of New South Wales contains, among its papers, the following: on Local Variations and Vibrations of the Earth's Surface, by H. C. RUSSELL, with five diagrams; on Causes of Decay of the Australian Forests, by Rev. P. MACPHERSON; on the History of Floods in the Hawesbury River, by J. P. JOSEPHSON; on the Characters of the Adelong Quartz-reefs, by S. H. COX; on the Ringal of the Northwestern Himalaya, by Dr. Brandes, besides others; preceded by the address of the President, H. C. Russell. The cause of decay in the Australian forests, after much investigation, was traced to the *Opossums*. The leaves of Eucalyptus were eaten and each margin thus deeply scolloped. This was proved to be the way with a captive opossum; and it was further proved that one opossum would devour about 200 leaves a night; and consequently shown that the 18,000 opossums killed annually in County Grant, Victoria, were sufficient to destroy upwards of 13,000 trees and lay bare a space of 700 acres, or more than a square mile.

OBITUARY.

ISAAC LEA.—Isaac Lea died at Philadelphia on the 8th of December last in his ninety-fifth year, after a life of enthusiastic devotion to science and great success in scientific work. He was born in Wilmington, Delaware, on the 4th of March. His residence in Philadelphia began when fifteen years of age; and at twenty-two, in 1814, he and his friend, Mr. Lardner Vanuxem, later Professor Vanuxem, of the Geological Survey of New York, became members of the Academy of Natural Sciences of that city. His contributions to science began and ended with the department of mineralogy. But his chief memoirs and works are devoted to the departments of modern conchology and some departments of paleontology. His investigation of the American Unios began in 1825 on receiving some specimens through Major Long, from the Ohio river; and when it closed in 1874, he had published thirteen volumes. The difficulties in discriminating species arising from varying forms in the shells he endeavored to overcome by a study of the animals, and accomplished much in this direction. His researches were extended to the fresh-water shells of other continents; and they included besides Unionidæ, also species of Melanidæ, Paludinidæ, Helicidæ, and other freshwater species. The other large field occupied by him was that of the Tertiary shells

of eastern North America. His attention was called to the shells in the Claiborne bluffs in 1829. His "contributions to Geology" in 1833, in which year he published a series of papers, and included all in a volume of 226 pages, embraced discriptions and figures of 221 species of Tertiary shells, from Maryland and New Jersey as well as Alabama. Later he described fossil shells, of Oolitic age from Grenada; Unio-like species from the Carboniferous of Pennsylvania; a fossil reptile (for which he instituted the genus *Clepsysaurus*) from the Juratrias of Pennsylvania; a paper (in 1854), on large foot-marks from the Subcarboniferous red sandstone of Pottsville, of which he published a grand lithographic plate, of natural size—the discovery carrying amphibians back geologically to an earlier period than before known; and papers on some feldspars.

The establishment of this Journal in 1818 owes much to Dr. Lea, who responded with zeal to a request from Professor Silliman for his "kind countenance and favor" and for "contributions to its pages," by procuring at once and sending on (April 3, 1818) the names of more than a dozen subscribers,* the last of whom has now passed away in his own decease, after the publication of the 132nd volume.

Mr. Lea was married in 1821 to Miss Carey, daughter of the well known Philadelphia publisher, Matthew Carey; and for thirty years he was also a partner in the publishing house. Mrs. Lea, a companion of congenial tastes and an amateur in botany, especially the department of forest trees of America and Europe, died in 1873. Three children survive him, Henry Charles Lea, Matthew Carey Lea and Miss Frances Lea.

Mr. Lea became a member of the American Philosophical Society in 1828; was President of the Academy of Natural Sciences of Philadelphia from 1853 to 1858; and was elected to honorary membership in many foreign scientific societies. He received the degree of Doctor of Laws from Harvard in 1852. A complete detailed list of the publications of Dr. Lea, with a biographical sketch, is contained in number 23 of the Bulletin of the United States National Museum, prepared by N. P. SCUDDER. It speaks of Dr. Lea in his 94th year, as still "blessed with good health, his mental and physical faculties unimpaired;" and so it continued to be until ten days before his decease.

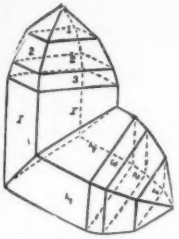
The Elements of Chemical Arithmetic with a short system of Elementary Qualitative Analysis, by J. Milnor Coit, Ph.D. 89 pp. 8vo. Boston, 1886 (D. C. Heath & Co.)

A Manual of Lithology, by EDWARD H. WILLIAMS. 135 pp. 16mo. New York, 1886 (John Wiley & Sons).

Causeries Scientifiques, Decouvertes et Moentions, Progrès de la Science et de l'Industrie, par Henri de Parvill, 25 tom année, 1885. Paris. 1887 (J. Rothschild). A popular volume telling of some of the recent advances made in scientific thought or investigation.

Lectures and Essays by the late Wm. K. Clifford, F.R.S., edited by Leslie Stephen and Frederick Pollock with an introduction by F. Pollock. Second Edition. 443 pp. 8vo. London and New York, 1886 (Macmillan & Co.).

* A list of these subscribers, in a letter from Dr. Lea, is published in volume xxvi, 1883, of this Journal, on page 79.



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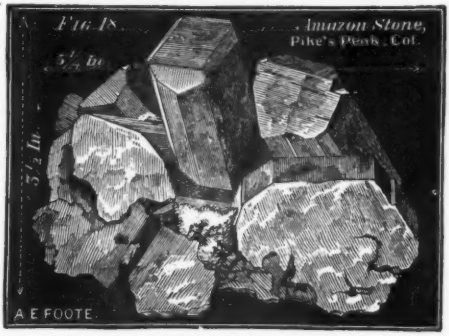

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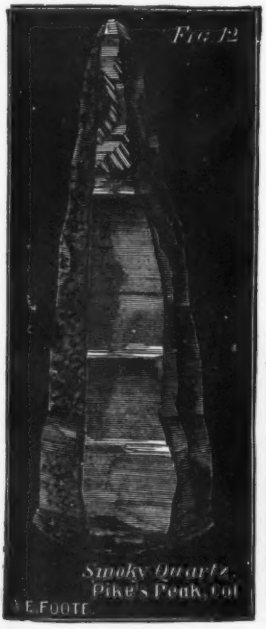

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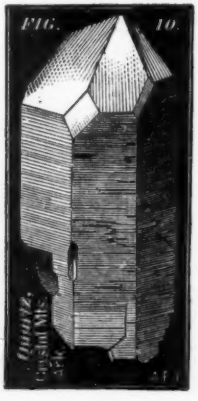

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